PRODUCT
ENGINEERING

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Only Those Who Play the Game Can Survive

COOPERATION is characteristic of the engineering profession. Why? The first explanation that comes to mind is based upon commercial considerations. But the commercial aspects are really a natural outgrowth of human relationships that existed long before our great industrial system came into being. The impelling forces that developed the spirit of cooperation can be traced to the strongest of all instincts—self-preservation.

History gives many instances wherein danger, misfortune or disaster have united the efforts of many for the preservation of the individual. Engendered by necessity, the spirit of cooperation was bred into the pioneers and colonists of America in their struggles against beasts, savages and the elements. Fighting was one phase of their united action. The other phase was that of providing for material needs, as when neighbors gathered for "house raising" or quilting parties, or to dip tallow candles at the fireside. It was only by such team-work that the sturdy settlers succeeded in conquering the wilderness—and only those who played the game survived.

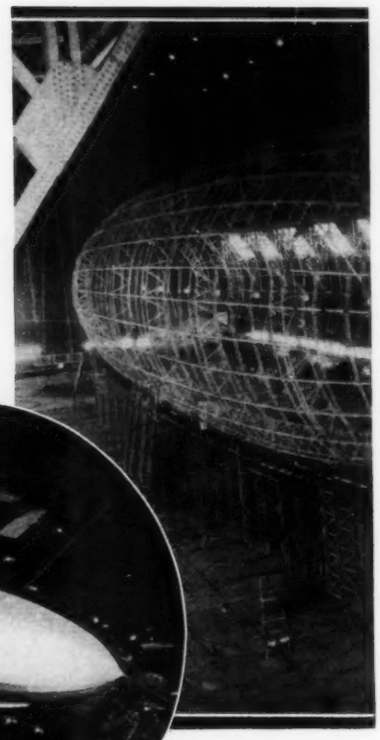
IN the course of time the engineering profession developed. Primarily, this profession conceives and executes the designs of products and the machinery and equipment for production and construction. Its function is to provide the material needs, and in its activities we see exhibited the same concerted action that characterized the early settlers.

Engineers conceived and established the boiler code of the A.S.M.E., neither at the behest nor with the sanction of legalized authority. The same can be said about the A.S.T.M. standards, and the S.A.E. standards, and many others. The American Standards Association was neither born of nor supported by governmental agencies, but is the result of the combined voluntary efforts of engineering societies. Many other similar instances could be cited. Each illustrates united action for a common purpose; a contribution toward lightening the burdens of labor and improving the conditions of living.

BUT standardization represents only one phase of teamwork in engineering. The same procedure is adopted in the development of individual products. Be it a "tin" toy or a locomotive, the final design is not the work of one individual, but the result of the coordinated efforts of many. Engineers who have specialized in materials, electrical parts, castings, stampings, bearings, finishes or whatever else the design problem might involve, are called in and consulted. It is true that these men represent manufacturers, but that does not alter the facts. Our leading article describes a splendid example of this sort of cooperative engineering.

No one engineer can be expert in all the ramifications of his profession. The best equipment for any engineer is a broad general knowledge of fundamental principles coupled with a specialized technical skill in one or perhaps two fields. Added to this, he must have an ability to manage. He must be able to select those to whom he intrusts the solution of special problems, and to coordinate their efforts. And above all, he must recognize his own limitations and must not permit fear, ego or an inferiority complex to deter him from exposing his own ignorance. He must not only welcome the cooperation of others in the solution of problems lying outside his immediate field, but in return he must also contribute his special knowledge. It is only by such teamwork that our new products can be developed successfully—and only those who play the game can survive.

Organized Engineering Makes the Macon



GEORGE F. NORDENHOLT

An account based on interviews with Dr. Karl Arnstein. The discussion on the design of the main frames was written by T. A. Knowles, a member of his staff. For the historical facts the author is indebted to Hugh Allen of the Goodyear-Zeppelin Corporation

THE words "Zeppelin" and "Airship" are often thought of synonymously because of the many innovations Count Zeppelin introduced to the airship art in its early stages of development. The invention and design of the first rigid ship was relatively of but passing moment. But the effects of the engineering and research organizations established by the energy, vision, courage and devotion of Count Zeppelin will be in evidence for many years. Achievements such as his, in the face of old age, poverty and disaster, probably have never been paralleled.

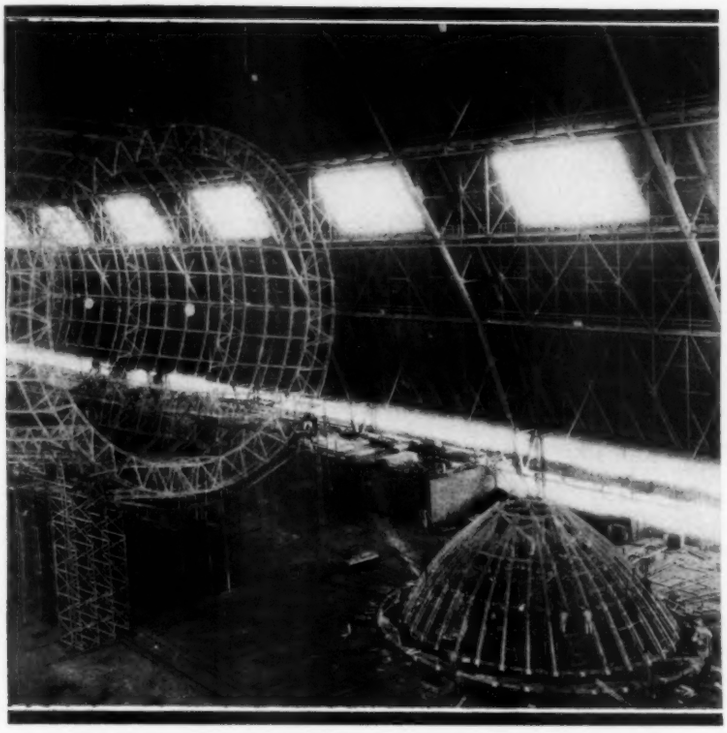
Not until after being retired from active service as an army officer, did Zeppelin begin his monumental work. At 56 he completed his first design. Then followed a hard struggle for financial support. After four years the first ship, 419 ft. long with two 16-hp. motors, was launched. It was a success. Three more were built, but the fourth was soon wrecked in a storm when engine trouble compelled a forced landing. At that time, it seemed that this financial loss to the then 69-year-old inventor was to doom his great undertaking to final failure.

But Count Zeppelin appealed to the German common people. Tradesmen, farmers, school teachers, mechanics and the like responded with $1,250,000. Great was this vote of confidence. Greater still was the unselfishness and devotion of the aged inventor to his cause. He refused the money for his personal use, but placed it in trust for founding the "Zeppelin Endowment for the Propagation of Air Navigation," and stipulated in its charter that all profits were to go back into the further development of aeronautics. Thus, born of disaster and reared by a genius, began one of the most courageous aeronautical development programs the world has even seen.

The Zeppelin Endowment became rich and powerful. It organized subsidiaries for building motors, airplanes, hangar buildings and the like. It established its own commercial operating company and, of greatest importance, carried on tremendous research activities.

Much of this progress would have been impossible were it not for the ability of Count Zeppelin to discover and develop men of vision and genius to carry his work to greater perfection. He needed better engines, and selected Maybach to develop them. Zeppelin fully recognized the necessity of applying scientific principles to the structural design problems. This work, he entrusted to Dr. Karl Arnstein, who within a short time because chief engineer of Luftschiffbau-Zeppelin. Under his supervision 68 ships had been built before the Inter-Allied Air Commission in 1924 put an end to building airships in Germany.

In the meantime, the Goodyear Tire & Rubber Company, which for many years had manufactured balloon fabric, began in 1911 to build balloons and non-rigid airships, an activity that was expanded considerably during the World War. In 1924 the Goodyear Tire & Rubber Com-



Inside the hangar at Akron showing the partially completed framework of the ship. The main rings are of triangular cross-section and support the wire networks that form the bulkheads between the gas cells. To the extreme left is shown the finished ship on a trial flight

pany acquired the Zeppelin patents. Paul W. Litchfield was made president of the newly organized Goodyear-Zeppelin Corporation and Dr. Karl Arnstein was induced to come to American to accept the position of vice-president in charge of engineering. With Dr. Arnstein came twelve of his technical experts. And thus it came about that we now find assembled in Akron, Ohio, a unique group of technical experts and engineers building the world's greatest airships, the designs of which incorporate the accumulated experience of Germany and the United States.

In view of this wealth of talent concentrated in their organization, it is not surprising that in 1927 the Goodyear-Zeppelin Corporation was awarded first prize in the airship design contest instituted by the United States Navy Department. A total of 37 designs had been submitted. The competition was reopened and in this second contest Goodyear-Zeppelin was awarded first, second and third place, and the company was given the contract to build two ships.

At this stage the development of airships had reached the point where further improvements could be attained only through technical researches and refinemnet of design. A study of previous ships indicated a number of desired improvements. The new ships were to be the largest, fastest and strongest ever built. This required a stronger and more rigid framework, a compact unit which incorporated all parts inside of the hull; maximum accessibility to all parts of the ship; minimum air resistance; a condensing system to recover water from the engine exhaust to make up for the loss of fuel weight, and maximum degree of control. These were the principal aims to be achieved in the design of these ships.

Previously, the framework of an airship consisted of longitudinal girders in conjunction with a single keel or backbone in the bottom of the ship; spaced circular frames were fastened to these longitudinal elements in transverse planes. This construction permitted a longitudinal passageway only at the bottom of the ship. The frames consisted of merely one main "circular" member of a wire network tightly stretched across. The network not only provided a bulkhead or partition to separate the individual gas bags in the hull, but the initial tension in the wires contributed materially to the stiffness of the frame.

A very perplexing problem arises when one attempts to undertake the design of a main frame-wire netting combination of this type. Since the contour of these frames is not rigid, it is necessary to internally brace the polygon by means of wires. These wires are intended to carry all loads in the plane of the ring and, if high factors of safety are desired, it is necessary to use wires of large cross-

An aggregation of experts developed the aeronautical design and established the exacting specifications for all the devices and materials. These were furnished by more than 800 manufacturers whose engineers contributed their specialized skill in meeting the requirements for the greatest airships ever built

sectional area. It can be readily demonstrated that the factor of safety cannot be chosen at will.

In conditions of abnormal pitch or of a deflated cell the loading is of a somewhat different character. Under these conditions there are large longitudinal forces which manifest themselves by the surging (or bulging) of the gas cells. These forces must be absorbed by the wire bulkheads, which in turn distribute them to the longitudinal strength members of the airship. This is done by permitting the netting to elongate and in this manner to adopt a shape which is better suited for the distribution of these loads. The more the diaphragm is permitted to shift, the better will be the approach to he optimum shape which would only transmit loads in the direction of the longitudinal girders.

The only bulkhead extension obtainable with the conventional wire braced frame, however, must come from the elongation of the individual wires under stress. Since the elongation of these wires under a given load is inversely proportional to the area of the wire, it follows that these wires must be as small as possible thus limiting the over-all factor of safety which can be obtained.

In analyzing this problem, two governing factors are apparent. First, the frames require the support of the wire network, and therefore the latter must be attached rigidly. Secondly, it is the rigidity of this connection between the frames and the network that causes the high tensile loads in the wires. Therefore, if the rings were designed so that they would in themselves be sufficiently strong, it would be permissible to use a resilient connection between the wire network and the ring. Such a design would be most desirable as the resilient connecting member could be chosen so that the bulkhead would have considerable distention under high lateral pressures, thereby requiring a relatively small tension in the wires; yet the distention of the bulkhead at normal operating conditions could be minimized by selecting the proper initial tension in the yielding connecting members. The undesired wandering of the center of the gas volume would thereby be practically eliminated. With such a design it would also be possible to choose the factor of safety for the wires of the bulkhead, use the smallest wires permissible, and thereby save considerable weight.

In developing the self-supporting main rings, a built-up construction of triangular cross-section, because of its inherent rigidity, was decided upon. Two parallel outer rings bound to a smaller inner ring through zig-zag members gave the triangular frame sections. By making the triangular cross-section large enough to serve as a cross gangway, it paved the way for many further improvements.

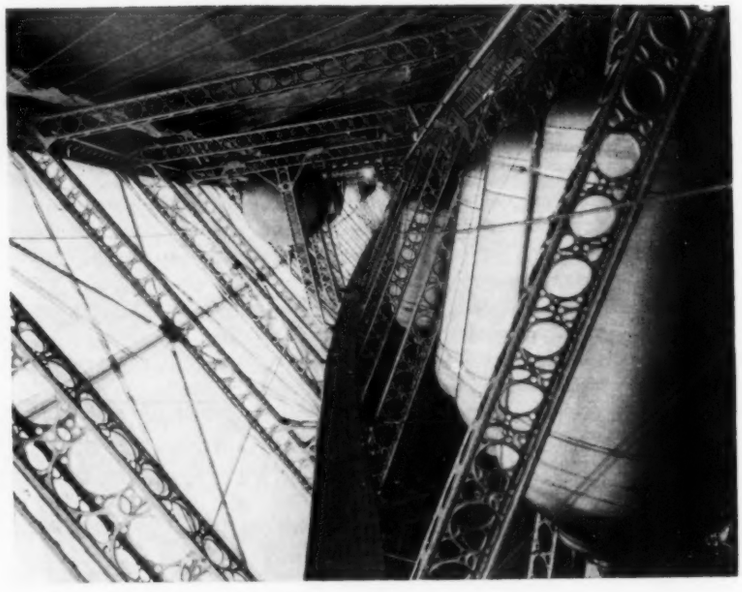
With the main frames not requiring any support from the wire network, it was permissible to attach the network to the inner ring through the medium of resilient members whose yielding had been pre-determined. In the construction as used on the Akron and Macon, this resilient member takes the form of pneumatic devices which exert sufficient initial tension so that the bulkhead is relatively rigid against small pressures and yet is permitted to bulge considerably when acted upon by large pressures. In the design of this wire-net bulkhead, it was necessary to guard against the abrasion of the gas-bag material by the wire-net bulkhead during its movement. For this reason, the mesh of the wire bulkhead is of rhomboidal shape, while the excess cell material is placed in the vicinity of the resilient elements. Thus was developed a design that eliminated the unfavorable elements and indeterminate factors that were inherent in the former main frames and bulkheads.

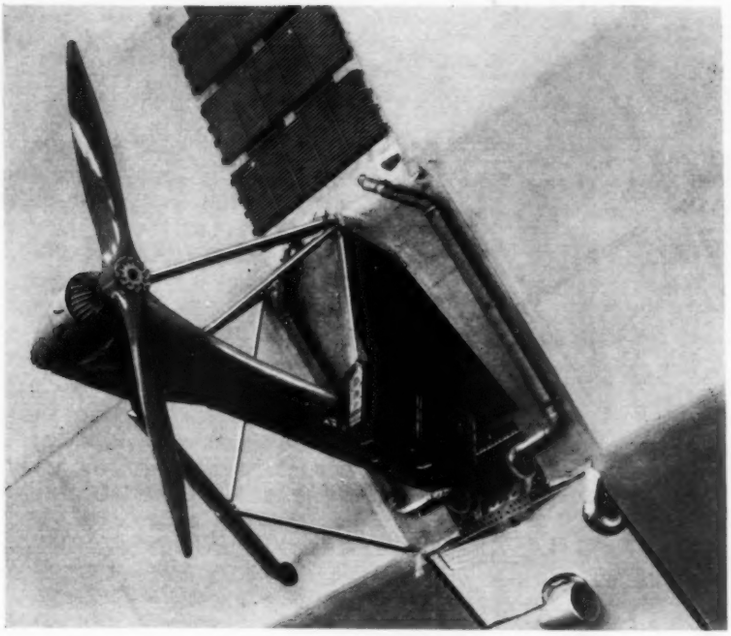
In place of a single keel, the new ships have three longitudinal members running practically the whole length of the ship, one at the top and two in the lower half at 45 deg. to each side of the vertical centerline. Adhering to the same principle of construction as used in the main frames, these longitudinal keels are also of hollow triangular cross-section and also serve as gangways, each giving access to each main frame. Between successive main frames are interposed three auxiliary frames.

The structural members are of duralumin, being fabricated out of strips ranging from about 6 to 9 in. in width. In the accompanying illustration can be seen how holes were punched into the strips and the edges flanged up to decrease the weight and yet increase the strength. Indeed, the perforated strips weigh only about one-half of the solid sheet and yet when they are built into girders, the resulting members are stronger than could be built from solid strips.

The theoretical strength calcula-

One of the three longitudinal members that extend practically the full length of the ship. Together with the main rings which are of similar cross-section, they serve as passage ways to any part of the ship





Directly above the propeller outrigger are the condenser tubes for the recovery of water from the exhaust gases. Even the distance the tubes extend beyond the hull surface was carefully calculated with regard to air resistance

tions were proven to be correct by extensive researches and investigations. These matters, together with the fundamental problems of stress distribution through the hull members were thoroughly investigated by means of models, full-size construction of unit parts, and finally by tests on the completed ship. For the determination of strains, instruments were developed which mechanically or electrically measured the extension or compression of the part. Measurements also were made acoustically through the tone emitted by a musical instrument string attached to the member being tested, and vibrated by electromagnetic excitation. The pitch of the tone changes with the extension of a load bearing member to which the string is attached, and by comparison with the tone of a calibrated tuning fork, the strain in the member can be calculated.

Of course, this improved structural design added greatly to inherent strength and rigidity, while the form of the structure made all sections of the ship accessible. This in turn made possible another great improvement, namely, to put the engine rooms entirely inside of the structure of the ship. Thus the air resistance of the former engine gondolas was materially reduced, the way was paved for swivelling the propellers, and with the engines located in readily accessible rooms, they could be adjusted or even repaired in flight.

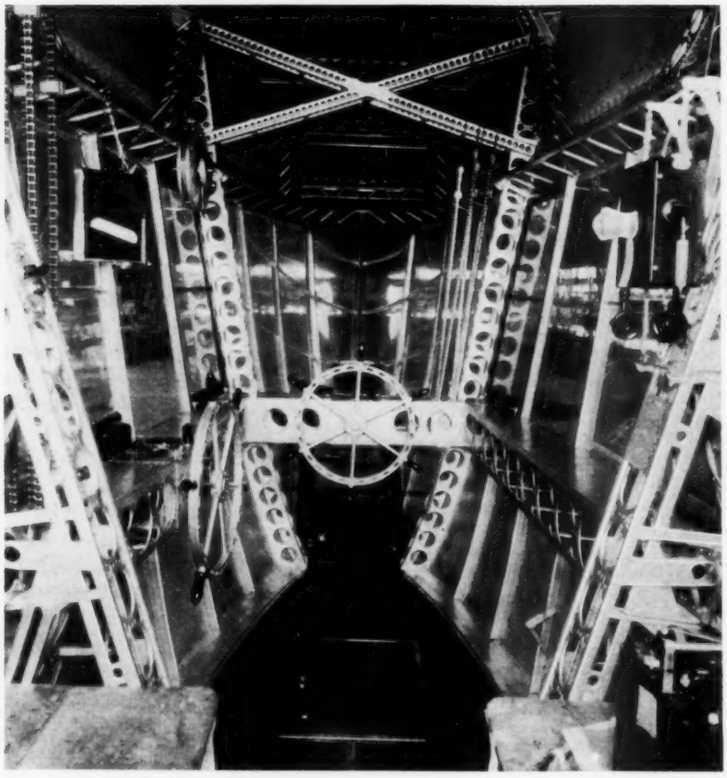
Four such engine rooms are on each side of the ship at main frames, the reversible engines being placed with their axes perpendicular to the longitudinal section of the ship. The propellers, supported by outriggers, are driven through a clutch with a bevel transmission at the propeller. This last makes it feasible to swing the propeller about the drive shaft as an axis and is accomplished by mounting the propeller shaft bearings in a housing that can be swiveled through 90 deg. The position of the housing is controlled by a worm drive that is mounted in an outer housing rigidly connected to the ship through the outrigger, the worm shaft being manually operated from the engine room. Thus the propeller can be put in a vertical or a horizontal plane and, as the engines are reversible, it makes it possible to exert a resultant thrust in any desired direction.

Being entirely new and therefore no data being available for checking the calculations, extremely careful design was demanded. An exact reckoning and calculation with reference to torsional vibrations was of greatest importance. When it is considered that it was merely the use of improper clutch spring replacements that caused the breaking of the propeller shafts of the Graf Zeppelin by permitting the building up of extremely high torsional vibrations, one can appreciate the exactness required in making these calculations. In order to make absolutely certain that there would be no complications, a full-size section of the hull was built, consisting of a portion of the main ring and side gangway, with the engine, propeller, and drive placed in position. Tests were then run and careful measurements taken to determine the character and magnitude of the stresses created. It must have been most gratifying to the engineers, and it is a tribute to their skill, that exact duplicates of this test set-up were built into the ship, the experiments indicating that the design was perfectly satisfactory from the torsional vibration standpoint.

Another interesting problem was the design of the condensers to recover the water vapor from the exhaust gases. These condensers, as shown in one of the accompanying illustrations, consist of a series of elliptical tubes with the major axis placed radial to the body of the ship and the tubes parallel to the longitudinal axis of the ship. The velocity of the air flowing past the ship is practically zero at the surface but increases rapidly at small distances from the hull. It was therefore necessary to select that location for the condenser tubes where the air velocity under normal operating conditions would be sufficient to carry off the required amount of heat. At the same time if these tubes were located too far beyond the surface of the hull they would present an excessive amount of frictional resistance because of the high air velocity.

Development of a heavy oil engine for airships is being awaited with great expectation. Diesel engines would eliminate the fire hazard and, in addition, have exceptionally low fuel cost. But Diesel engines in straight helium airships would bring up the question of ballast water on account of the low hydrogen content of the fuel and the high air-to-gas ratio used. Researches with reference to the fuel and the construction of Diesel motors that would make possible retrieving the water, are now in process.

The hull of a Zeppelin uses a three-



Inside one of the control rooms which are built integral with the hull instead of being placed in suspended gondolas. Every detail was designed for minimum weight

layer principle of construction. The innermost skin or shell is composed of the gas holders or cells. These are surrounded and protected by the substantial metal structure that carries the principal loads. The third and outermost shell is a layer of fabric usually called the outer cover. It is the purpose of this outer cover to protect the inner part of the ship from the elements and to present a smooth surface that will minimize frictional resistance to the air. However, the rigid fastening of the outer cover to the framework makes it possible for this fabric to perform a second function, namely to carry a substantial part of the shear loads. That this is so has been proven by measurements. Therefore the outer cover can be looked upon as having a load carrying capacity which is particularly important in case one portion of the load-carrying members of the ribbed structure should be damaged. This gives an added factor of safety to the construction.

It is interesting to follow the development of materials for the outer cover. The first Zeppelins had impregnated cotton called "Pegamoid." Later, a waterproofing process was added, resulting in material called "Millrain-Process." This material had a markedly diminished water absorption. Further researches revealed that the application of cellulose acetate gave the cotton cloth a smooth, water-tight surface and, at the same time increased its resistance to tearing. Aluminum powder was later added to the final coats of the acetate cellulose to protect the material from deterioration. This metallic "paint" also had the advantage that through better reflecting power of the sunlight it diminished temperature variation of the gas in the cells. The superiority of this type of outer shell covering is demonstrated by the Los Angeles which, after seven years of service, still has three-fourths of its original outer cover in useful condition.

From time to time, metallic outer shells have been proposed for airships. In the opinion of Dr. Arnstein, at the present time a fabric outer hull which has been carefully made and applied is the most dependable outer shell available for airships. The thinnest metal is too heavy for the purpose and, in the case of the newer ships, would increase the weight by approximately 10 tons.

In previous airships the gas cells were made of goldbeater skins. These skins are small sections from the intestines of steers. Some idea of the amount of labor involved in making gas cells with this material can be gained from the fact that goldbeater skins from 400,000 cattle went into the gas cells of the Los Angeles, each one of the skins being cemented to reinforcing fabric by hand, a laborious task requiring much precision. It was this tremendous expense that impelled the Goodyear Laboratories to undertake a research looking to the development of a substitute. Two were evolved, one a rubberized fabric and the other a gelatin latex fabric in which many coats of latex and gelatin were spread over fabric. This last material even excelled the goldbeater skins in that it was no heavier and showed considerably higher resistance to gas diffusion.

Some idea of the stupendous magnitude of this engineering undertaking can be gained from the fact that parts and materials were furnished by more than 800 different manufacturers, and practically all of the material was of special design and construction. The Aluminum Company of American developed a special cold rolled duralumin which exceeded the exacting specifications set up. The American Steel & Wire Company produced a hard steel wire highly resistant to corrosion, 30 miles of it being used for girder bracing and for the spider-webbed bulkheads separating the gas cells. Westinghouse furnished the most powerful radio set ever installed in aircraft and devices for communciation and electrical equipment. The Cleveland Pneumatic Tool Company helped develop the resilient elements that connect the wire bulkheads to the main frames. The Allison Engineering Company worked out the detailed problems of transmission and gearing in accordance with Goodyear-Zeppelin basic designs.

In this respect the executive engineers followed the philosophy of Count Zeppelin who searched for and found the geniuses who created the machines and devices necessary for the successful completion of his ships. Thus, directed by Paul W. Litchfield and Dr. Karl Arnstein, this vast undertaking represents the combined efforts of the best engineering minds available, each an expert in his own field.

PRODUCT DEVELOPMENTS

New Uses of Materials—Automotive Design in Agricultural Machinery—Convertible Road Roller—Built-In Motor Drive —Recent Applications of Parts and Units—Railway Air Conditioner—A Dynamic Weigher—New Marine Engines

▸ New Uses of Materials

The current stringency of currency has brought two new materials into the field of coining. In the City of Dayton the people are trying out aluminum coins for local circulation. In Midland, Mich., the Dow Chemical Company used magnesium in the form of Dowmetal to make tokens which were used to pay off employees last week. These tokens will be redeemable in standard currency later.

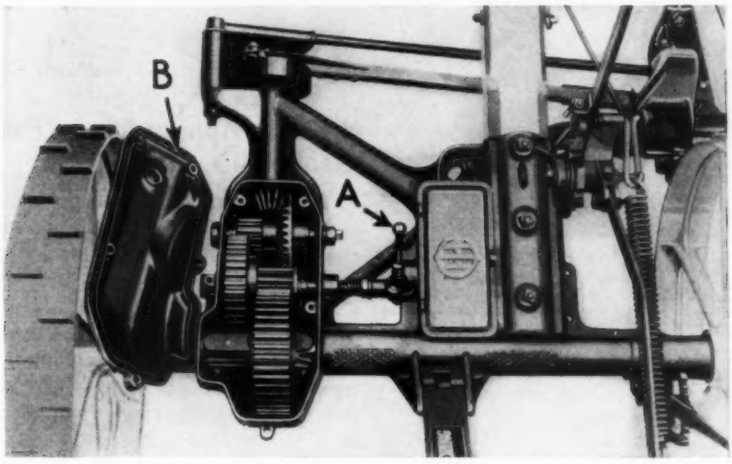
Ordinary steel nails are now being fitted with lead heads to protect them against climatic and acid deterioration. Lead bullets are coined onto the heads of steel nails in a dial-fed coining press at the rate of better than 8,000 per hour. The tools were designed and built by the F. J. Littell Machine Company, of Chicago. When these nails are driven with a hammer the leaded head is not distorted as much as one would suppose.

Rubber-lined drums for muriatic acid, nitric acid and chromic acid are expected eventually to replace carboys as shipping containers. The reasons for this belief, given by Goodrich, are lower freight rates, lower freight weights, ease of handling and no breakage, and less storage space required.

Opax, a tasteless and odorless wax-like material, is being used to impregnate cellulose bottles made in the form of standard half pint, pint and quart glass milk bottles. The development work on this product was done at the Mellon Institute on an industrial fellowship sustained by the F. M. Burt Company, Ltd., of Buffalo. The bottles will not break upon dropping on a concrete floor, will not soften under constant exposure to water or lactic acid, and will pass through the usual filling and capping equipment without any serious changes in the practice that is followed in filling glass bottles. They are opaque, one-third better heat-insulated than glass, and can be supplied in any color. Containers which can be sealed by crimping have been made for tea, butter and lard.

Recent developments indicate further possible uses of rubber for floor covering and other purposes. Under the trade name of Vulcateen, the B. F. Goodrich Rubber Company is marketing a line of rubber kitchen rugs and simulated orientals. Durability of the color and pattern is assured by the manufacturing method used. The color pigment, mixed with some "rubbery" material, is applied with an air gun, the patterns and color thereby becoming an integral part of the mat or rug.

Inclosed gears of the automotive type running in oil feature this new McCormick-Deering mower. The gasketed cover *B* makes the top of the gear case dustproof and oil-tight. Leather oil seals in steel cases do the same for the shaft bearing. Clutch lever *A* throws the gear in or out of action. The large diameter flywheel shaft runs in automotive-type brass bushings; the main drive shaft in four roller bearings

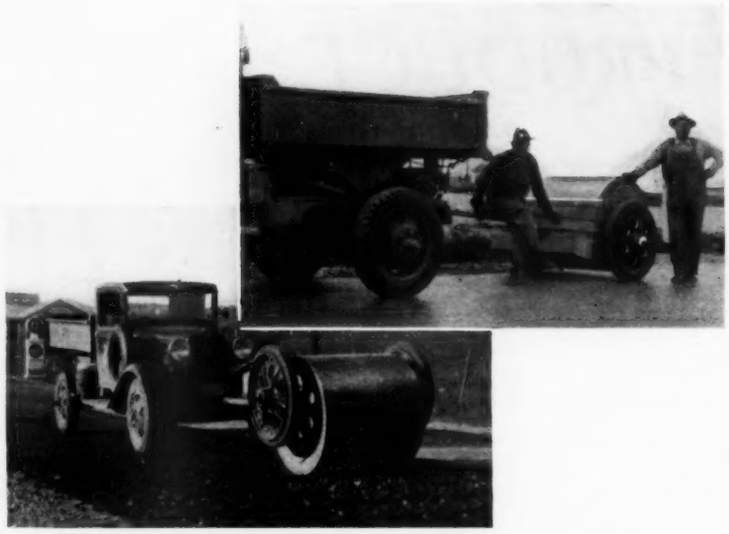


▸ Convertible Road Roller

Texas is 750 miles wide, 800 miles from north to south. Her distances are therefore magnificent. They are so magnificent, in fact, that it often costs as much to drive a gasoline-powered road roller out to a highway job and back again as it does to do the job itself and the time consumed on the two trips is considerable. With this problem to face the Alamo Iron Works developed the wheeled roller illustrated in the two halftones. One shows it in operating position ready to be pushed ahead of a road truck like a lawn mower. The other shows it turned over onto its rubber-tired wheels for speedy transportation to and from the job behind the truck. The machine's cast-iron roller is 36 in. long and in the hubs are babbitted bearings. Two eccentrically

located hubs are fitted with heavy steel pins on which are mounted the cast-iron, solid rubber-tired, Timken bearing equipped, transport wheels. The tongue and clevis by which the roller is pushed or pulled are so balanced that it is possible for two men to lift up the tongue, pass it over the roller and let it down on the other side so that the rubber-tired wheels lift the roller 5 in. off the ground. The pole can be set to any desired angle in order to permit the roller to be operated on a soft road shoulder while the truck stays on the hard surface.

Removable end covers allow the roller to be filled with dirt or sand to increase its weight. A water tank with a drip device for moistening the roller surface, combined with a knife-edged scraper, serve to keep the surface free from pick-up.



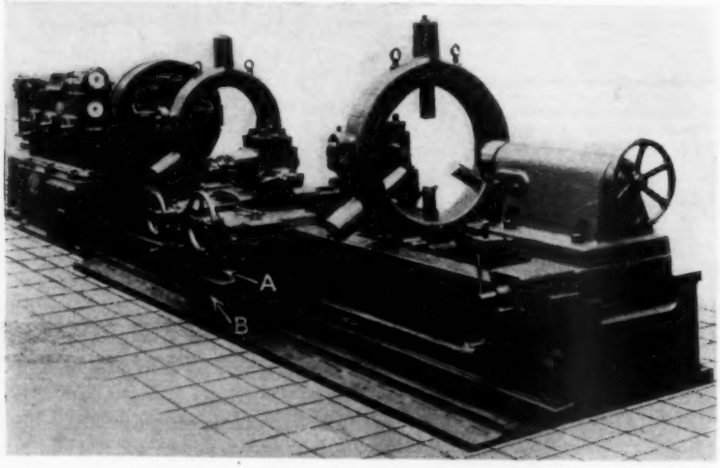
In Texas, distances between highway repair stations are considerable. This roller was designed to be speeded to the job on its rubber-tired wheels

▸ Built-In Motor Drive

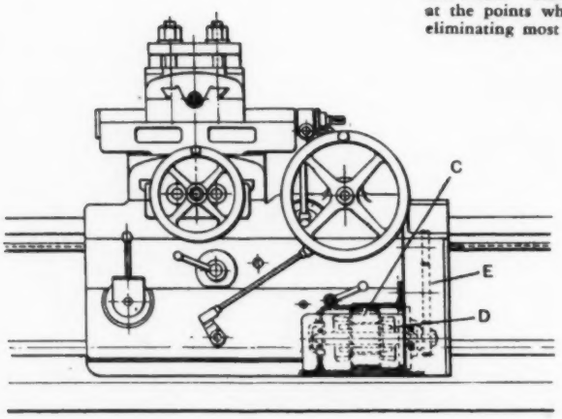
Instead of one main motor driving the various units of the lathe through mechanical transmission, the 20-in. high-speed lathe recently developed by Craven Bros., Ltd., of Manchester, England, has separate auxiliary motors built in at the points where power is required.

The saddle feeds are actuated by separate 1½-hp., 4-pole induction motors, one being built into each of the twin saddles. In the accompanying picture, the head of the arrow marked *A* shows where the motor is housed in the casing, while arrow *B* indicates the location of the contactor unit.

Details as given in the line drawing show how the motor is mounted in the apron. The stator *C* is inserted directly in the apron casting. The extended shaft of the rotor *D* drives the longitudinal and transverse mechanism through the inclosed gear wheels *E*. The completely built-in design gives maximum economy of space, efficiency of operation and an attractive appearance.



Individual auxiliary motors are built-in at the points where power is required, thereby eliminating most of the mechanical transmission



The stator *C* is inserted directly in the apron casting and the rotor *D* drives the longitudinal and traverse feeds through the inclosed gears *E*

▸ Recent Applications of Parts and Units

When yarn is spun at constant speed the tension varies and with it the quality of the product. A year's experience with a new and simple alternating current, variable-speed driving equipment indicates that this equipment solves the problem. The equipment consists of a simple induction motor of slip-ring type controlled by a line starter and combined with a spin regulator and a spin rheostat. A combination of cams and chain drive varies the spinning speed to maintain constant tension in the yarn.

A small disk-type thermostat is used in the capacitor-type refrigerator motors of the Westinghouse Electric & Mfg. Company. The thermo-

stat disconnects the motor from the line when the motor gets too hot, and keeps the motor disconnected until it has cooled sufficiently to safely carry the load.

A British printer has established a photo-electric cell control which stops the press within two seconds if the paper breaks in operation. The paper feed passes between the cell and the light source. If a break occurs the light is no longer interrupted and the cell operates a relay which stops the press.

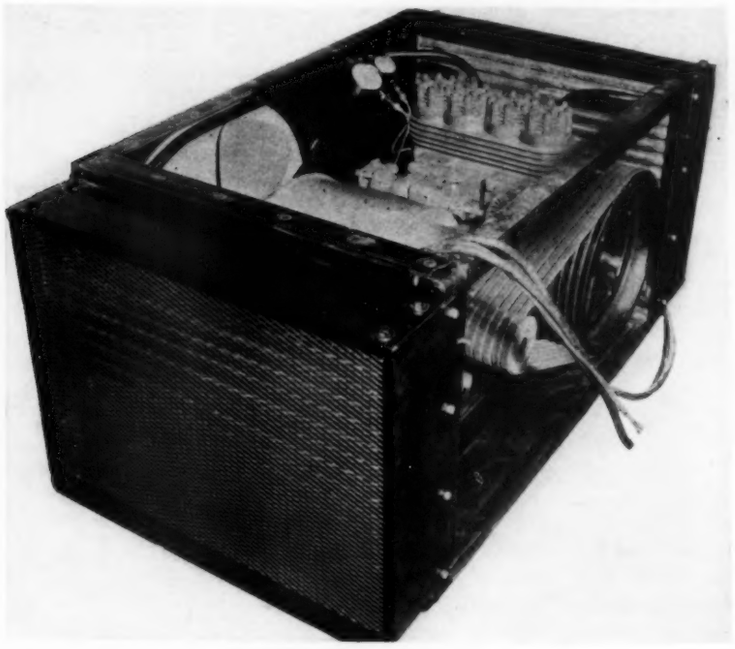
Variations in the length of a rayon strip determine the frequency of an oscillating vacuum tube which is the control element in an industrial humidity recorder. Changes in the frequency induced by changes in the length of the rayon strip caused by variations in humidity operate the control intended to correct the humidity.

Very close regulation of temperature in an electrically heated oven has been obtained by means of a photo-electric cell located behind the mercury column of the thermometer giving the oven temperatures. A finely focused light source is interrupted by the mercury in the thermometer when the critical temperature is reached. The interruption operates the photo-cell and thereby actuates a switch that cuts off the heating current.

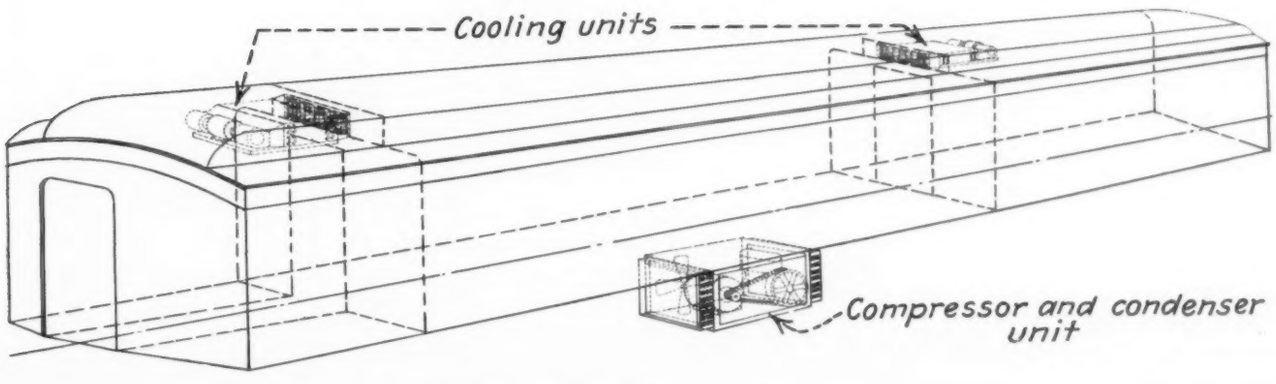
▸ Railway Air Conditioner

Within a few weeks now the thermometer will have climbed to the point where passengers in old-fashioned railway cars will suffer as they always have in hot weather, while those in air-conditioned equipment will acclaim the accomplishments of the product engineer. Simplicity, compactness and light weight distinguish the railway air conditioning unit developed by the Frigidaire Corporation in conjunction with railway engineers and the General Motors Research Laboratories in Detroit. One of the objectives of the designers of this equipment was the avoidance of alterations in existing car structures. Another objective was flexibility which has been attained to the extent that these units can be adapted for use on anything from compartment sleepers to ordinary day coaches. Still another was ease of maintenance. It is claimed that this has been so well worked out that even a Pullman porter can take care of all the personal attention that is necessary. Installations will be made in regular railroad car shops by railroad men at a minimum of expense.

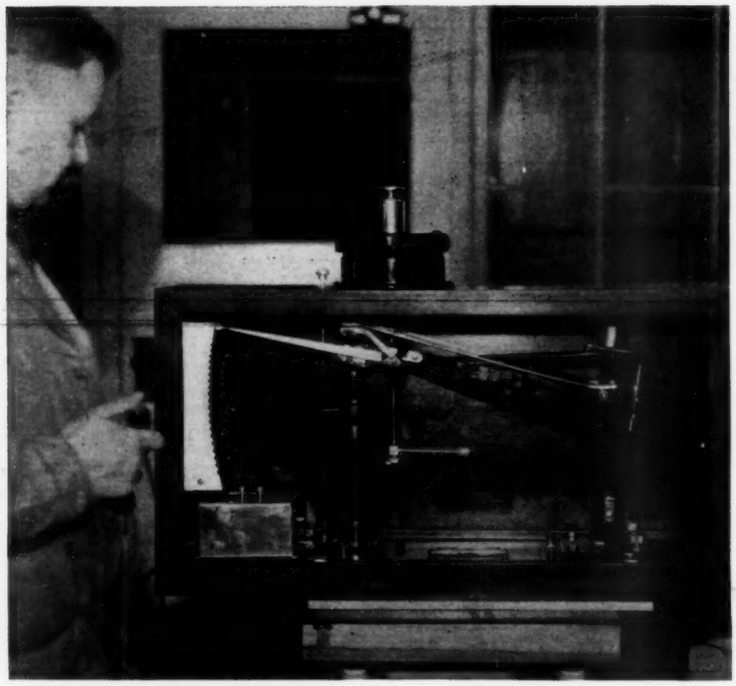
The diagram shows the location of the two cooling units and the compressor units in a standard diner. The halftone illustration portrays the compressor unit which is driven by a 7½-hp. motor to produce five tons of refrigeration and a 10-hp. motor for seven tons. The refrigerant is dichlorodifluoromethane, better known as F-12 or Freon. The compressor has four cylinders cast enbloc, 3⅛ in. square. For five tons of refrigeration the compressor operates at 425 r.p.m., for six tons at 510, for seven tons at



Railway air conditioning compressor unit developed by Frigidaire is applicable to several types of cars



Location of compressor and cooling units in a diner. Structural alterations are avoided



Pendulum principle permits combination of speed and accuracy in Dynamic Weigher

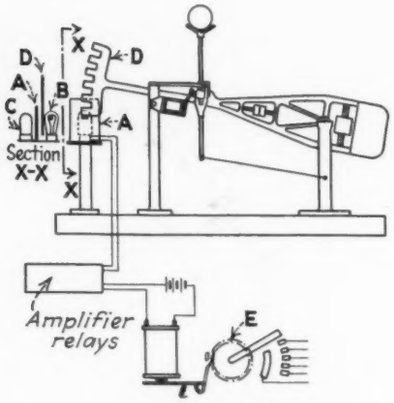
600. Six V-belts constitute the drive. Lubrication is force feed up to piston pin and careful arrangements have been made to isolate the lubricant from the refrigerant. Motors for the customary railroad voltages, a.c. or d.c., are available or the drive may be direct from the car axle. The finned tube condenser has 660 sq.ft. of surface and is air-cooled by a motor fan of 8,000 cu.ft. per minute capacity driven by a $\frac{1}{4}$-hp. motor.

▸ A Dynamic Weigher

Speed of operation and accuracy of performance have been looked upon heretofore as irreconcilable factors in a weighing device. In the dynamic weigher recently announced by Toledo Precision Devices, Inc., this reconciliation has been brought about through the application of the pendulum principle. If a free-swinging pendulum is pulled out of the vertical position and then released it will swing to a point the distance of which beyond the vertical is dependent upon the distance the pendulum was pulled out of its vertical position. If a weight is placed upon one side of the pendulum, the center of mass of the pendulum moves toward that side. The greater the weight added the farther will the center of mass move. Consequently, if the pendulum is held against movement and a weight is placed upon it at one side of its vertical center line it will when released swing through an arc the length of which is dependent upon the amount of added weight. This is just what has been done in the dynamic weigher, as will be evident from the two illustrations.

The moving member is essentially a horizontal pendulum equipped with a pointer that moves along a vertical scale. An electrically operated catch holds the pendulum in the zero position until the object to be weighed has been placed upon the table or hopper. When the catch is released, the pointer swings down along the scale and then returns to the neutral position. The operator watches the pointer and records the reading at the extreme position. The device may be arranged to read actual weight or to record variations from a given standard. For laboratory use, the device is equipped with a poise and removable weight. The accuracy attained is of the order of one in one hundred thousand.

A further refinement, as illustrated in the diagram, is an electric eye classifier. The chart *A* in this form of the device is provided with a slot upon one side of which is located a lamp *B* from which light passes through the slot in the chart to the photo-electric tube *C*. The indicating hand *D* is provided with a series of extensions which, as the hand swings downwardly under the influence of the load on the receiver successively interrupts the passage of light through the slot. The photo-electric tube is connected through the amplifier to the impulse-operated switch *E*, which may control as many circuits as there are desired classifications. As each tooth of the extension on the hand interrupts the passage of light to the tube, an impulse is transmitted to the switch. The circuits controlled by the switch may be employed to divert articles or packages tested into



Dynamic Weigher equipped with photo-cell control for special applications

bins or on the conveyors according to their under- or overweight; or they may be employed to control indicators or signals to operators of trimming machines or even to such trimming machines themselves.

▸ New Marine Engines

Embodying the same principle of horizontal-opposed cylinders as used in the White bus engine (*P.E.*—p. 479, December, 1932), the Gifford-Wood Company has developed a line of marine engines. These engines are of the four-cycle, four-cylinder, horizontal-opposed type. Features resulting from this type of construction are compactness, low center of gravity, light weight and minimum vibration. According to George N. Hickey, the designer, this type of engine represents the next definite trend not only in the marine field but also in automotive design.

Equations for the Design of Involute Cams

FRANCIS W. SHAW
Consulting Engineer, England

The view of the involute presented by Fig. 1 will likely be new to most readers. Yet it is a view that reveals its features in a clearer light than does the usual mathematical presentation.

The likeness of the four figures is more than casual; in their own system of coordinates they are, indeed, identical, all being parabolas of like height and base. The parabola at B has been bent, without change in the length of its vertical axis or of its ordinates, these latter remaining normal to the axis until, as at Z, the figure lies evenly upon a circle.

As shall be shown, if x be made equal to $\frac{1}{2}y^2$ and y equal to the arc subtending any angle θ, the axis of the parabola, in the bending, becomes an involute curve, and the cross-hatched (inner) portion of the parabola an involute surface. Fig. 1 illustrates the divers relationships when the circle at Z has unity radius.

Then, since this involute surface has, as is to be shown, exactly half the area of the cross-hatched portion of the parabola, itself a parabola, the simple equation for the area of the parabola becomes available for the area of the involute surface, the answer it yields being merely halved. That the areas of the complete figures are identical, the following analysis will show.

Let the figures at B and Z be conceived as composed of the same number of infinitesimal elements e of like axial width w at equal distances from 0. While the triangles at Z have the same width w as the rectangles at B, their bases are double the bases of the rectangles and therefore the complete figures have like areas.

But the triangles of the cross-hatched portion of the figure at Z have but half the base and half the height of the triangles of the complete figure. Therefore, the portion has a quarter the area of the whole and, consequently, half the area of half the complete figure at B. As the equation for the area of a parabola, or a semi-parabola if we may so name the cross-hatched portion of the figure, of height x and base y is $A = \frac{2}{3}xy$, the area of the involute surface will be:

$$A = \frac{1}{3}xy \qquad (1)$$

if it be granted that the cross-hatched surface at Z is really involute.

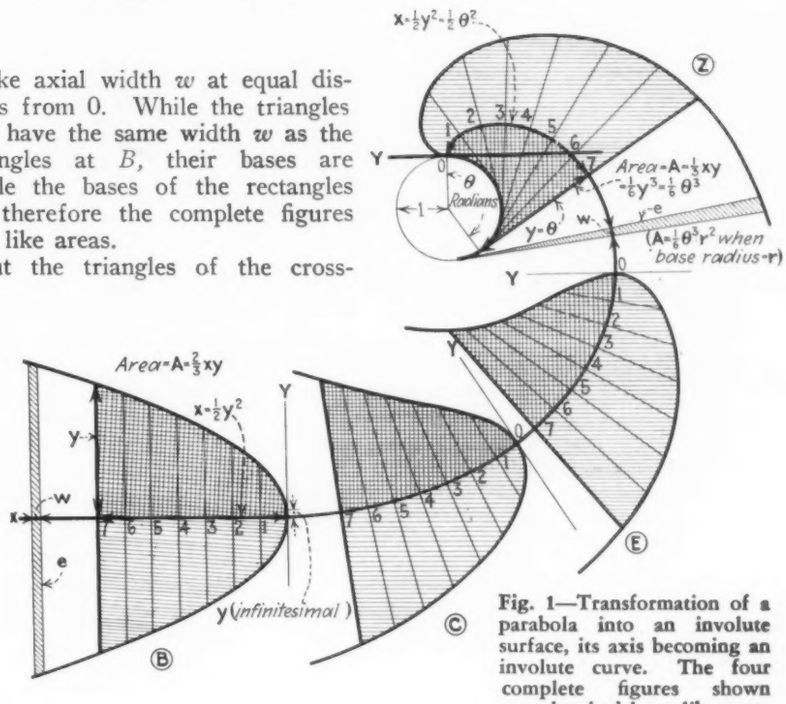


Fig. 1—Transformation of a parabola into an involute surface, its axis becoming an involute curve. The four complete figures shown cross-hatched have like areas

Unfortunately, in a cam such as Fig. 2 depicts, upon the design of which this discussion hinges, generally neither x nor y is known but must be discovered from the desired relation of the rotary movement of the cam to the rectilinear movement it must impart.

Now, if the tangent t in Fig. 2 be regarded as the classic cord whereby the involute curve has been traced, the angle θ through which the cord has unwound is precisely equal to the angle subtended by the arc laid bare in the unwinding—that is, equal to

▸ After a simple derivation of the fundamental equations for involute cams, this article shows how to calculate maximum sliding speed and to proportion the abutment.
▸ In the May number will be given an analysis of the effect of cam shape on valve spring disturbances by R. V. Hutchinson, General Aviation Manufacturing Corp.

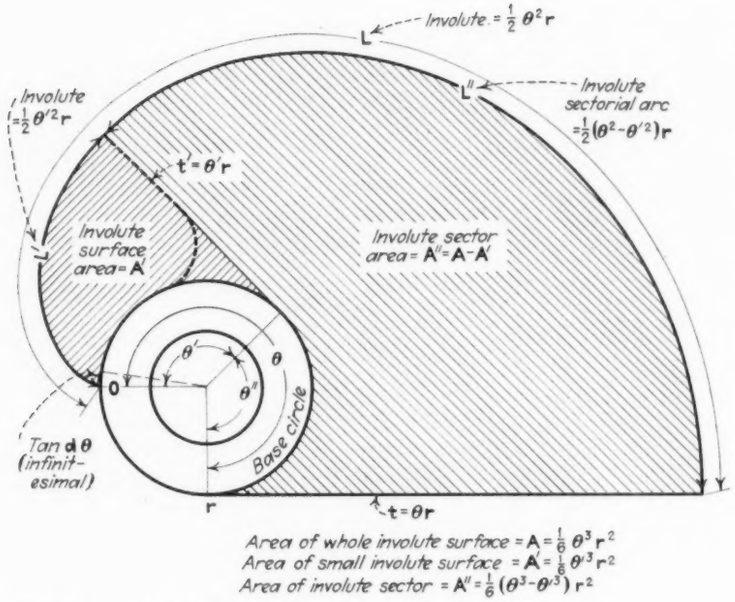

Involute = $\frac{1}{2}\theta^2 r$
Involute sectorial arc = $\frac{1}{2}(\theta^2-\theta'^2)r$
Involute = $\frac{1}{2}\theta'^2 r$
$t=\theta' r$
Involute surface area = A'
Involute sector area = A''=A-A'
Tan dθ (infinitesimal)
Base circle
$t=\theta r$
Area of whole involute surface = $A=\frac{1}{6}\theta^3 r^2$
Area of small involute surface = $A'=\frac{1}{6}\theta'^3 r^2$
Area of involute sector = $A''=\frac{1}{6}(\theta^3-\theta'^3)r^2$

Fig. 2—Herein is illustrated the derivation of a formula for the length of curves and for area

the arc Or measured clockwise. And t, the length of cord unwound, is equal to the same arc. If the angle θ be expressed in radians and the base radius, which shall be termed the radius of the base circle, be unity, both the arc and the tangent will be equal to θ, the number of radians. At the moment when the cord begins to unwind—that is, when θ is an infinitesimal angle, the tangent t is also infinitesimal, corresponding to infinitesimal y at the vertex of the parabola. Since t grows at the same rate at θ, for it is always equal to it, and it is the instantaneous radius of curvature of the involute curve, the mean radius of curvature must be equal to the mean value of t—that is, to $\frac{1}{2}(0+\theta)$. It therefore follows that the length of an involute curve from the point of origin, generated on a base circle of unity radius, is equal to the arc of a circle of $\frac{1}{2}\theta$ radius subtending an angle of θ radians. Or in the form of an equation the length L of involute curve when the base radius is unity is:

$$L = \frac{1}{2}\theta \times \theta = \frac{1}{2}\theta^2 \qquad (2)$$

When the base radius is r,

$$L = \frac{1}{2}\theta^2 r \qquad (3)$$

Equation (2) is identical with that for the parabola at A, for $L = x$ and $\theta = y$.

In thus identifying the two equations, we do not wish to identify also the two figures, except in their own system of coordinates. All we seek to show is the coincidence of the axes and ordinates, for identicalness of these shows that the area of the involute surface, as we have seen, is half that of the corresponding parabola.

Expressing x and y in terms of θ, we can now rewrite Equation (1) as follows:

$$A = \frac{1}{3}xy = \frac{1}{3}\times\frac{1}{2}\theta^2\times\theta = \frac{1}{6}\theta^3 \qquad (4)$$

This will be the area of the involute surface when base radius is unity, and since areas of similar figures vary as the squares of linear dimensions, the general equation will be:

$$A = \frac{1}{6}\theta^3 r^2 \qquad (5)$$

But, not every involute curve embodied in cam design starts at the base circle, though its theoretical origin is there. The curve may be cut away, say, to the dotted line t' as in Fig. 2, the curve now being what we shall term an involute sectorial arc, and the surface it limits an involute sector. The length of the curve is now L'' and the area A''.

From Fig. 2 we note that $L'' = L - L'$, both L and L' being curves originating at the base circle. Obviously, then, from Equation (2) we have for the length of involute sectorial arc when base radius is unity:

$$L'' = \frac{1}{2}(\theta^2 - \theta'^2) \qquad (6)$$

For the area A'' of involute sector when base radius is unity:

$$A'' = \frac{1}{6}(\theta^3 - \theta'^3) \qquad (7)$$

Knowing that in similar figures lengths are proportional and areas are proportional to the squares of linear dimensions, we are able to write down the general formulas for L'' and A''—that is, where the base circle radius r is other than unity.

$$L'' = \frac{1}{2}(\theta^2 - \theta'^2)r \qquad (8)$$

$$A'' = \frac{1}{6}(\theta^3 - \theta'^3)r^2 \qquad (9)$$

In order properly to proportion the surfaces, we may desire to learn either the maximum speed at which the periphery slides on the abutment or the sliding speed at the moment of most intense loading.

Referring to Fig. 3, let the velocity of the base circle, assumed to be constant, be denoted by v and the

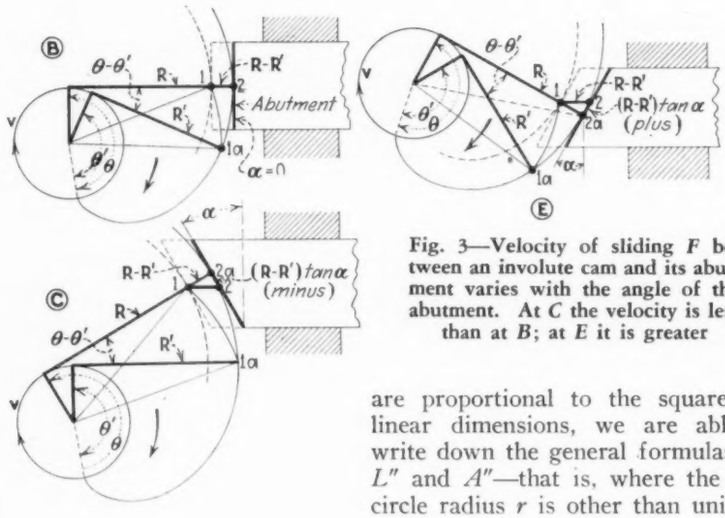


Fig. 3—Velocity of sliding F between an involute cam and its abutment varies with the angle of the abutment. At C the velocity is less than at B; at E it is greater

speed at which a given point upon the involute is moving (not necessarily sliding) from a given point on the abutment, denoted by V. Then V/v will be the ratio of the distance the point on the involute moves in the smallest conceivable interval of time to the distance a point on the base circle moves in the same time interval.

Now, as the cam turns through any angle $\theta - \theta'$ its radius of action increases from R' to R and the abutment, whatever be its inclination, moves a distance equal to $R - R'$. At the same time a point *1* of involute has moved to the position *1a*. It is evident, then, that a length of the involute extending between *2* and *1a* has slid over the abutment. But

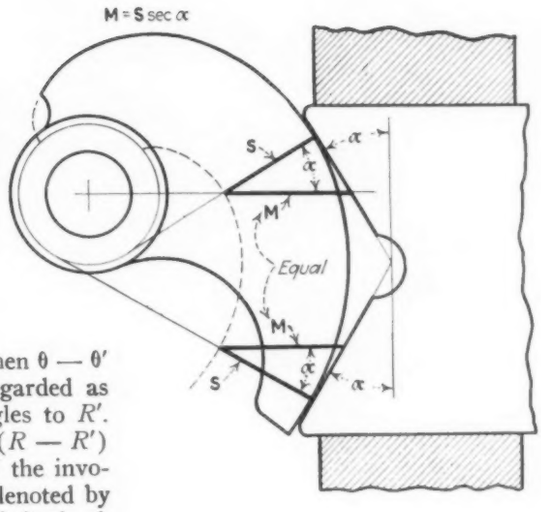


Fig. 5—To reduce loads and stresses the abutments may be duplicated. Inclining the abutment gives the same effect as increasing the throw of the cam

sector between *2* and *2a*, when $\theta - \theta'$ is infinitesimal, may be regarded as a straight line at right-angles to R'. Then it is clearly equal to $(R - R')$ tan α. Let the velocity of the involute between *2* and *2a* be denoted by V'. As the distance is infinitesimal,

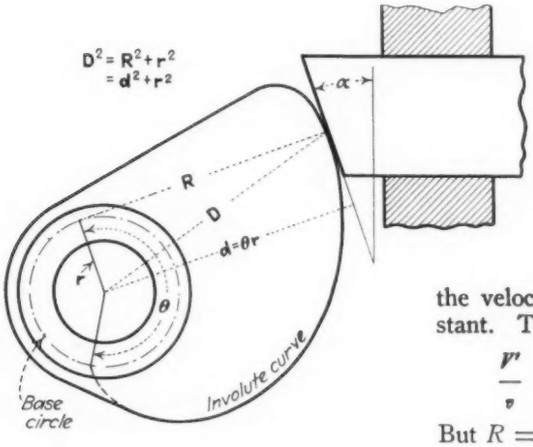


Fig. 4—Where either D or d is given, the angle θ can be determined readily, d being the shortest distance between the abutment and the center of the camshaft

only at B is this length equal to the sectorial arc subtending the angle $\theta - \theta'$. At C it is shorter and at E it is longer by the distance between *2* and *2a*, for in these cases the point of contact on the abutment is a moving point. For Case B it is clear from Equation (8) that:

$$\frac{V}{v} = \frac{(\theta^2 - \theta'^2)\, r\,/\,2}{(\theta - \theta')\, r} = \frac{(\theta + \theta')\,(\theta - \theta')\,/\,2}{(\theta - \theta')} = \frac{\theta + \theta'}{2}$$

When the difference between the angles θ and θ' is infinitesimal, this is the equivalent of $V/v = 2\theta/2 = \theta$, from which, manifestly for Case B, the velocity of sliding V of the involute curve, is:

$$V = \theta v \qquad (10)$$

Now consider Case C. The short the velocity can be regarded as constant. Then,

$$\frac{V'}{v} = \frac{(R - R')\tan\alpha}{(\theta - \theta')\, r}$$

But $R = \theta r$ and $R' = \theta' r$, therefore:

$$\frac{V'}{v} = \frac{(\theta - \theta')\, r \tan\alpha}{(\theta - \theta')\, r} = \tan\alpha$$

It is now seen that, since $V/v = \theta$, from Equation 10, we have for Case C:

$$\frac{V - V'}{v} = \theta - \tan\alpha \qquad (11)$$

In a similar manner it can be shown that Case E is met by the equation:

$$\frac{V + V'}{v} = \theta + \tan\alpha \qquad (12)$$

Now let the velocity V, $V - V'$ or $V + V'$ be denoted by s. Then, the ratio of the distance the involute moves upon the abutment to the distance a point on the base circle moves will be s/v, which for Case $B = \theta$, for Case C equals $\theta - \tan\alpha$, and for Case E equals $\theta + \tan\alpha$; from which it now follows that:

For Case B,

$$s = \theta v \qquad (13)$$

For Case C,

$$s = (\theta - \tan\alpha)\, v \qquad (14)$$

For Case E,

$$s = (\theta + \tan\alpha)\, v \qquad (15)$$

If in Equations (14) and (15) α be put at zero, the bracketed expressions reduce to θ, both equations then being the equivalent of Equation (13), a fact which, in a measure, goes to prove their derivation.

Ordinarily, it would be the maximum sliding velocity that one would require to ascertain. That would occur when the action was at the maximum cam radius.

A word now concerning the angle θ. The radius of the cam may depend upon a more or less fixed location of the abutment relative to the camshaft, as in Fig. 4. If the dimension d has been fixed, θ is readily determinable, for $d = R = \theta r$, from which the angle between origin of involute and contact point on abutment will be:

$$\theta = \frac{d}{r} = \frac{R}{r} \qquad (16)$$

in which d is the shortest distance between abutment and center of camshaft.

If the distance D to the point of contact be fixed. it will be clear that:

$$\theta \text{ (radians)} = \sqrt{(D^2 - r^2)}\,/\,r = \text{angle between origin of involute and contact point on abutment} \qquad (17)$$

How to be able to alter the stroke of an involute cam may be of interest to those who are studying the grinding of involute gear teeth.

In this cam, the throw is $T - T' = S$. The sliding movement M, when the abutments are inclined to any

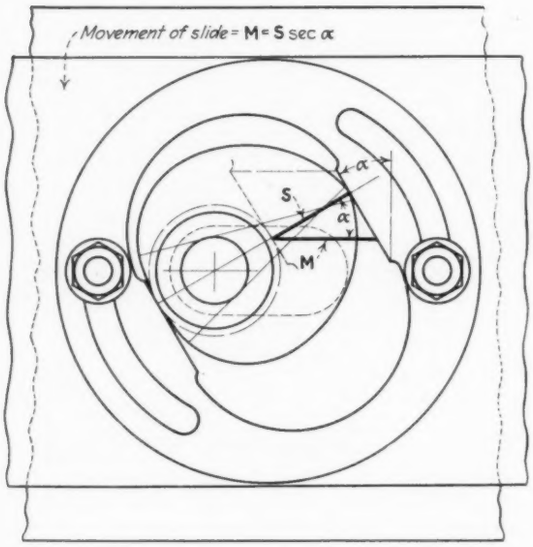


Fig. 6—Method of varying the movement of a cam driven slide. Movement can be increased but not decreased. Cams of this type give uniform rectilinear motion for the greater part of their stroke, with gradual acceleration and retardation

angle α, becomes, as the diagram clearly shows:

$$M = S \sec \alpha \qquad (18)$$

The sliding movement can never be decreased to less than the cam throw, for the secant of an angle is never less than unity. Equation (18) applies if the abutment is inclined in the opposite direction, permitting of the arrangement of Fig. 5, a valuable construction if care be exercised in getting contact at both abutments.

May we add that it is preferable to incline the abutment, for the reason that wear is distributed over a greater surface. Where a cam is wholly involute, or if the abutment is always in contact with the involute portion, a non-inclined abutment may be hollowed out to the maximum cam radius. Inclined abutments may be duplicated, as shown in Fig. 5, thereby reducing the unit loads and stresses.

From what has been said concerning the effect of different abutment angles on the rubbing speed, it might reasonably be inferred that different abutment angles may connote different rates of rectilinear movement. And if this is true, it should be obvious that if the abutment be made adjustable to different angles, thereby is provided a happy medium for varying the sliding movement of the abutment element; in effect, of varying the cam throw—a hint, by the way, to designers of machines for milling short slots. Fig. 6 illustrates a suitable device in principle.

Designing with Two-Ply Stainless

S. L. INGERSOLL

Vice-President and Director of Research
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In a broad way it might be stated that the handling of two-ply stainless steel follows the practices established for ordinary mild steel. This new material is being produced in any one of the principal basic formulas for stainless steel. The thickness of the stainless steel in relation to the total thickness of the sheet may be varied so that almost any commercial application problem can be handled. In the production of this two-ply material the finished sheets are rolled from a composite ingot, the surface of the stainless steel part of the ingot having been polished before the mild steel is applied. This is particularly important, for if a high polish is required in the finished product, the polishing becomes a simple operation.

Uniformity of the stainless ply in relation to the total thickness of the sheet is accounted for by the fact that the stainless portion of the ingot is rolled prior to pouring the composite ingot. The final percentage of thickness of the stainless ply to the total thickness of the finished sheet is thus accurately controlled in the rolling.

On account of the relatively small thickness of the tough and resistant stainless ply as compared to the total thickness of the sheet, this two-ply metal can be fabricated with the same equipment used on like gages of ordinary soft steel. The material may be deep drawn, stamped, formed, welded and polished. And it offers possibilities in the form of tubes and pipes, bars and shapes as well as sheets.

This material is also adaptable to welding by gas or electric methods, successful procedure having been worked out to produce lap, butt, "V" and flange welds. For the thinner gages, as from 16 to 10 gage, a close fitting butt weld may be made using a stainless steel welding rod. The weld should be made from the stainless side; with the proper amperage for the various thicknesses of plate a homogeneous stainless weld for both plys is effected.

The character of the two-ply metal limits its use to those applications where an unbroken clad surface will be exposed to the corrosion, heat or abrasion. Thus it will not ordinarily be used where the application involves piercing the metal as in screens for gravel and ore graders. However, for tanks, vats, kettles, and digesters, the stainless clad sheets would find wide application where the corrosion resisting properties of the stainless surface are of value.

In applications where some degree of protection or polish is desired on the mild steel side, as well as that furnished by the stainless surface, the carbon steel side may be given a low temperature enamel coating. Or it may be protected by aluminum, asphaltic or other resistant paints, or plated by Parkerizing, Udilyting and the like. It is predicted that the cost of the two-ply stainless, which is from 40 per cent to 50 per cent less than the cost of solid metals of like characteristics, will bring it within the reach of many applications where the resistance of a stainless surface has been desirable, but where the cost of solid metals have made their use uneconomical. The fact that the process of manufacture so lends itself to large tonnage production indicates that the major uses will be in machinery and equipment for the mining, processing, food and metal working branches of industry, rather than the more limited fields of instruments, cutlery, small hardware and the like.

LEV. A. TROFIMOV

Development Engineer
Electric Controller & Manufacturing Company

Engineering Problems Demand Thinking in Four Directions

WHEN industry adopted research a new type of engineer appeared —the product development engineer. His position can be defined as that of a modern industrial inventor, or an engineer whose specialty is the function of solving industrial technical problems, especially when solution is not obvious from research data.

It naturally follows that if the product development engineer exists as a specialist, there must also be a product development technique. In other words, there must be some kind of a theory of development engineering. I wonder if the expression, "Need is the mother of a new product," could not be regarded as a first principle of such theory.

In any event there seems to be a pronounced relation between the need and the engineering problem. Although they are intimately related, need is not a problem from the engineering point of view. Improvements in comfort, economy of labor and material, and simplicity of our existing machinery are all standing needs obvious to anyone. From here evolve the engineering problems—what is the best way to meet the need.

The first feature that distinguishes the need from the problem is the language. The former is expressed in everyday language and is understood by all, while the latter is stated in engineering terms. For instance, "the elimination of noise in a typewriter" is a statement expressing the need, while "the reduction or elimination of an impact of a part *A* against a part *B* for the purpose of reducing vibration and sound" is a statement of a problem.

Another distinguishing feature is that as a rule there are several problems in one need. Take for instance the above-mentioned need of elimination of noise. Besides this problem there may be that of the absorption of vibrations produced by the impact of the part *A* on the part *B*. Or the problem may be one of changing the audible frequency of vibration produced by this impact into a frequency that lies outside the auditory range of the average human ear. Notice the difference between these problems as indicated by the words: reduction or elimination, absorption, change.

It is well to remember that the same need may be satisfied in several different ways. The market value of the product resulting from the solution depends upon the choice of the particular problem to satisfy the need.

This relation of need and problem is not the same in all products. There are products whose market value depends entirely upon the correct estimation of the need and not upon the solution. For instance, an automobile radio control attached to the steering wheel post "right at the finger tips" has marketable value only if the need for such a convenience really exists and is big enough to justify the manufacturing of such controls. It is not much of a problem to design the control but it certainly is a difficult matter to estimate the probable sales. Consider further the combination of an electric fan and electric heater, which makes it possible to distribute quickly throughout the room the heat from the heater. Here again, the commercial success of the product depends upon the correct estimation of the need or demand in the market.

The product development engineer is chiefly concerned with the problem. The estimation of need is usually accomplished by specially organized means and is conveyed to the product development engineer. On the basis of this information he formulates his problem. He must understand the need and be careful not to confuse the elements of it with the elements of problem. For instance, "the riding comfort" in the motor car has long been a standing need which gave rise to many problems in automotive engineering. On rough roads the body of the car is subjected to vibration and shocks. One may feel constrained to make a statement that the problem is "to eliminate the shocks and vibrations of the motor car body." Such a statement has little value for an engineer because it is not a statement of the problem but is a modified statement of the need. The statement of the problem must be given in physical terms and must contain an assertion of the cause and its effect.

Directions of Solution

Thus the statement of the problem will be: "To reduce or eliminate the uncomfortable oscillations of the vehicle body caused by the impact of the wheels upon the road." This is a statement of the problem because it is expressed in engineering language and secondly, it clearly contains a cause—the impact of the wheel upon the road, and its effect—the uncomfortable oscillations of the body.

If the problem is put in this or similar form the engineer can at once begin his work toward a solution. He has two definite facts, cause and effect, and with the help of well known and simple methods he can develop a number of possible solutions. This method we shall call a memorandum because it can be used conven-

iently with the expectation of finding a suggestion for the direction in which the best possible solution may lie. After having established definitely the cause and effect that led to the problem, a memorandum for analysis of the statement of problem can be set forth as follows:

Direction I. Vary the cause and the effect will vary accordingly.
Direction II. Keep the cause unaltered and try to vary the effect.
Direction III. Vary both the cause and the effect and try to find the combination that will lead to a solution.
Direction IV. Remove the cause entirely.

Direction I. If it is possible to decrease the impact of the wheel with the road to a reasonably low value, the problem is solved. The impact depends upon the condition of the road, the weight and speed of the car and the condition of the wheel. All these conditions except the last cannot be changed by the engineer. The rim of the wheel, however, can be changed so as to reduce the total magnitude of the impact. Such reasoning might have suggested the use of pneumatic tires. The important point to understand here is that the purpose of the tires is not to absorb or change the effect (the oscillations) but to decrease the cause (the impact).

Direction II. Keep the cause unaltered and try to vary the effect. The need calls for comfortable riding. This does not mean that there must be no oscillation of any kind. Investigation as to why the oscillations from the impact of the wheel upon the road are so uncomfortable discloses that the reason lies in their period of vibration, which is very short and therefore jerky. The idea suggests itself that if we change the short-period oscillations into long-period oscillations, comfort will be obtained and the problem solved. Automobile springs are a partial solution in this direction. Their purpose or function is to receive the short-period vibrations and transmit to the body the vibrations of a longer period. This solution in turn gave rise to the problem of the damping of the long-period oscillations, which was solved by the shock absorbers.

We also may think of the springs as devices which receive an energy of impact in an extremely short time and deliver the same amount of energy to the body in a much longer time. This solution is of the type of changing the effect without substantially reducing it. It might be possible to actually reduce the effect by absorbing the energy of the impact as it comes from the axle. Some sort of friction devices between the axle and the frame may provide a proper solution.

Direction III. Suggestions obtained by following direction I and II taken separately, according to experience are not sufficient to meet the need of comfortable riding. Our memorandum, in such cases, reminds us that by varying both the cause and the effect we may find the combination that will solve the problem. In fact such a combination is responsible for the good riding comfort of the modern motor car.

Direction IV. The memorandum presents one more possibility, namely, the entire removal of the cause. In the above example it is hardly possible, unless the approach is from the first direction, that of reducing the cause to zero. However, in some cases it is possible to remove the cause entirely without approaching the solution from the first direction. In the effort to obtain a good mechanical joint between the pure tungsten button and the iron screw in manufacturing tungsten contacts for automobile coils and vibrators the problem was to reduce or eliminate the presence of the metallic oxides that caused poor joints. The cause of the trouble was presence of the metallic oxide. The proper flux considerably reduced the cause, whereas performing the brazing in a hot hydrogen atmosphere removed the cause entirely because the original oxide was reduced to the pure metal and no oxide could be formed during the brazing operation. This is an excellent demonstration of the fourth direction of solution which calls for permanent removal of the cause of the undesired effect.

One Direction Thinking

The familiar expression "I never thought of it," whenever somebody suggests a slightly different way of doing the same thing, indicates the peculiar property of our minds in assuming and pursuing one direction of thinking to the exclusion of other possible directions. I do not think it has anything to do with a type of mind, it is rather a habit of using the mind. Suppose an engineer using our memorandum finds a good suggestion for solution along the first direction and will not take trouble to investigate the remaining three. He is likely to assume this one direction and keep on it without arriving at a solution, forgetting that there are three further possibilities to help him in his difficulty. Some one comes along and suggests "Why not leave the cause as it is and try to change the effect?" "I never thought of it," will surely be the answer!

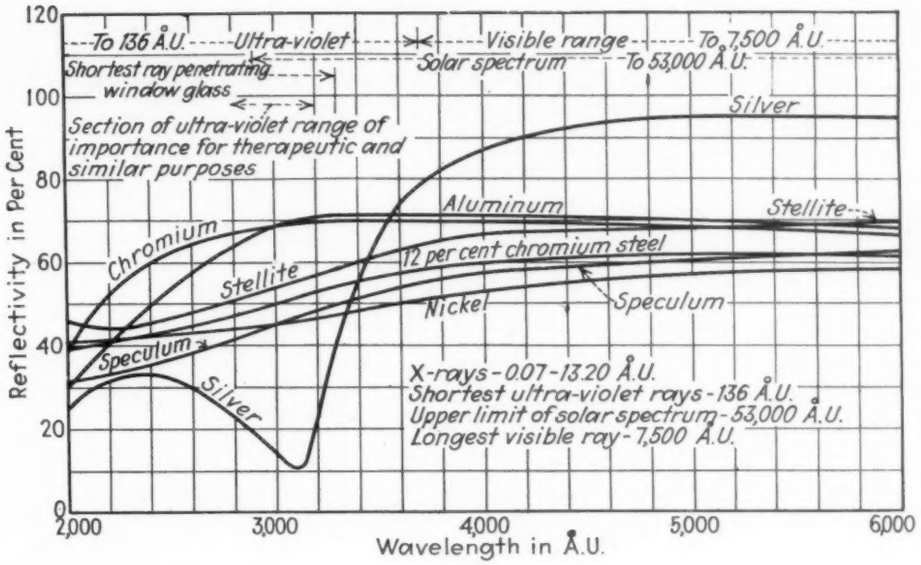
To guard against this inertia of the mind it is advisable to acquire a habit of investigating at first all four directions without stopping long on any one of them. Also, to repeat the complete investigation several times during the work in a chosen direction.

In our school days a teacher of arithmetic used to urge us to read the problem before starting to solve it. In engineering work we very often disregard this simple advice and begin to solve the problem without really knowing what the problem is. We know the need and think it constitutes a problem. It is very good practice indeed and may be considered as one of the important elements of development technique to take time and patience to establish beyond any reasonable doubt just what the problem is, regardless of who did the same work previously. In the theory of development engineering it may be termed as "establishing the statement of the problem."

Method Is Needed

This memorandum method may be superfluous for the engineer who unconsciously gathers information on the need, sifts the elements of the problem, welds them into a correct statement and sees clearly the cause and effect. Such engineers are exceptions. However, industry as a whole cannot be dependent upon exceptions. It lives and progresses by the effort of the average man. A company's future cannot be tied up with the exceptionally able man in the development department. There are not enough of them to go around. This is the reason we see the growth of product development engineering as a distinct profession. It is simply a natural effort of industry to substitute the organized effort of average men for what was supplied in the past by exceptional personalities. For this reason we need the memorandum.

This analysis is a demonstration (I would like to say a proof) of one of many possible thought-organizing devices, the assemblage of which constitutes development engineering technique.



Curves showing for different metals their reflectivity in the range of ultra-violet and visible wave lengths

Metals for Reflectors

R. C. ROETGER
Electro Metallurgical Sales Corporation

As the size of telescopes, arc lamps, flood lamps and similar equipment increased, silvered glass reflectors began to exhibit chemical and physical shortcomings. The silvering did not have long life, would not stand abuse and tarnished easily. Cleaning or polishing deformed the surface. Frequent re-silvering was costly, and although lacquering protected the surface, it reduced the reflectivity at least 20 per cent and the lacquer coating was easily blackened and distorted by fingerprints.

For therapeutic lamps, flood lamps, headlights and other lighting equipment there is great need for metal reflectors that will be permanent, will not tarnish, can be cleaned easily, can be manufactured by stamping or drawing and have a stable surface at the elevated working temperatures (about 300 deg. C.) encountered in some service. Considerable experimental work is being done on bronze, stainless steel, aluminum, duralumin, Hyb-lum, Haynes Stellite and chromium-plated copper or brass to serve as metals for reflectors.

The curves shown here give the percentage reflectivity of several metals at various wave lengths. The wave length of light is usually measured in Angstrom units (*A.U.*), one unit being one ten-millionth of a millimeter. To a large extent the interest of the engineer is limited to those reflectors efficient in the visible range of the spectrum; but the reflectivity of the ultra-violet between 2800 and 3200 *A.U.* is of importance for therapeutic and other reasons.

Examination of the curves will at first lead to the assumption that silver or silver plate is unquestionably the best material for a metal reflector for the visible range. However, other factors must be considered.

Haynes Stellite possesses a comparatively high and uniform reflectivity and has the advantages of exceptional hardness (resistance to scratching and deforming of the surface) and resistance to tarnishing. As it cannot be stamped, spun or drawn to shape, it is unsuitable for automobile lamp reflectors and similar articles that, for economic reasons, are made by one of the above processes. It is an excellent material for astronomical mirrors and scientific instruments where speed and expense of manufacture are not dominating factors. Haynes Stellite is being used for mirrors in telescopes, microscopes and other scientific instruments.

Stainless steels and certain nickel alloys possess many good qualities. Some are easily worked, are unbreakable, do not tarnish much, are hard and tough enough to permit cleaning and polishing. However, the surface oxidizes at about 300 deg. *C.*, giving the light a bluish or brownish color, which is undesirable in scientific instruments. The use of stainless steels for all classes of reflectors from large flood lamps to the small mirrors of a lady's compact is being investigated, and trials indicate favorable results.

Aluminum and nickel have both favorable and unfavorable attributes. Aluminum is light and has a fairly high reflectivity; but the transparent oxide, which is present at low temperatures, becomes much less transparent at about 300 deg. *C.* Nickel tarnishes readily and has low reflectivity. It can, however, be cleaned and polished without much danger to the surface.

Hyb-lum is an aluminum-chromium-nickel alloy having somewhat better mechanical properties than plain aluminum. Its reflectivity is 10 per cent higher than aluminum in the ultra violet range, but is the same as aluminum in the visible range. It can be fabricated readily.

Chromium, although hard and unworkable itself, is quite ductile when deposited as a plating, and chromium-plated copper or brass can be stamped easily and without injury to the coating. Chromium, which has good reflectivity, will stand up well at the working temperatures, and is not subject to attack by moisture or sulphur fumes, which severely tarnish silver. Chlorine atmosphere and polishes containing hydro-chloric acid must be avoided, as they attack chromium.

Applications of

K. L. HERRMANN
Bantam Ball Bearing Company

Formula for Needle Bearings

$$R = 0.16\,PLC \Big/ D\sqrt[3]{S}$$

R = rated safe load, lb. L = length of rollers
P = number of rollers S = speed in r.p.m.
D = diameter of rollers C = constant

Diameter of roller

1/16	3/32	1/8	5/32	3/16	7/32	1/4
Constant C						
275	618	1,100	1,718	2,475	3,368	4,400

Available Sizes

*0.0625 diam. x 0.625 long	0.1250 diam. x 0.375 long
0.0625 diam. x 0.656 long	0.1250 diam. x 0.750 long
0.0937 diam. x 0.484 long	*0.1250 diam. x 0.875 long
*0.0937 diam. x 0.750 long	0.1870 diam. x 1.000 long

*Proposed standard sizes

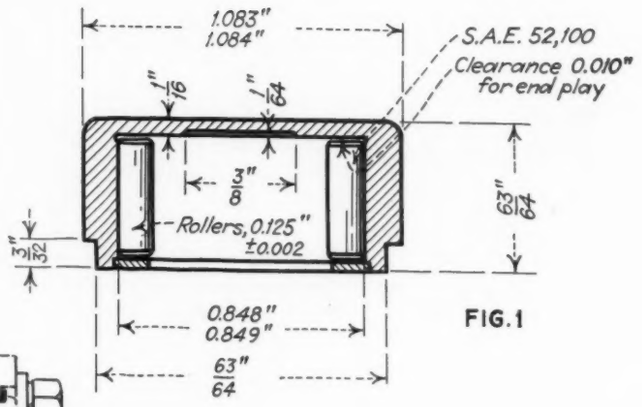


FIG.1

Fig. 1—The journal inside the bushing is 0.597 + 0.000, —0.001 in. Load carried is from 525 lb. to 2,000 lb. for short duration. Outer bushing and journal are S.A.E.-1020 steel carburized to depth of 1/32 to 3/64 in.

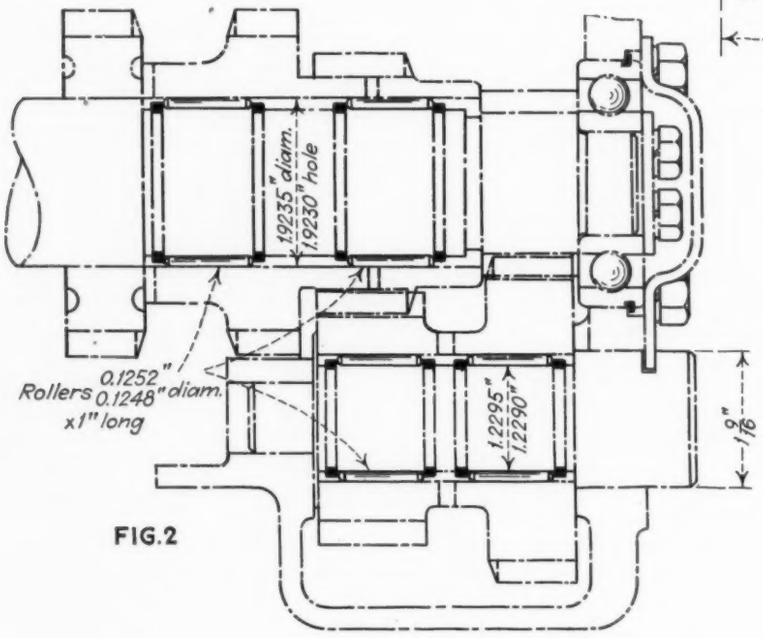


FIG.2

Fig. 2—Installation of needle bearings for a truck transmission. Snap rings locate the rollers endwise, the same principle being applied to the ball bearing mounting.

Fig. 3—Needle bearings as installed on a gear pump. The packing nut also serves to retain one of the bearings.

Fig. 4—Typical needle bearing mounting in an automobile transmission. A snap ring separates the two sets of rollers.

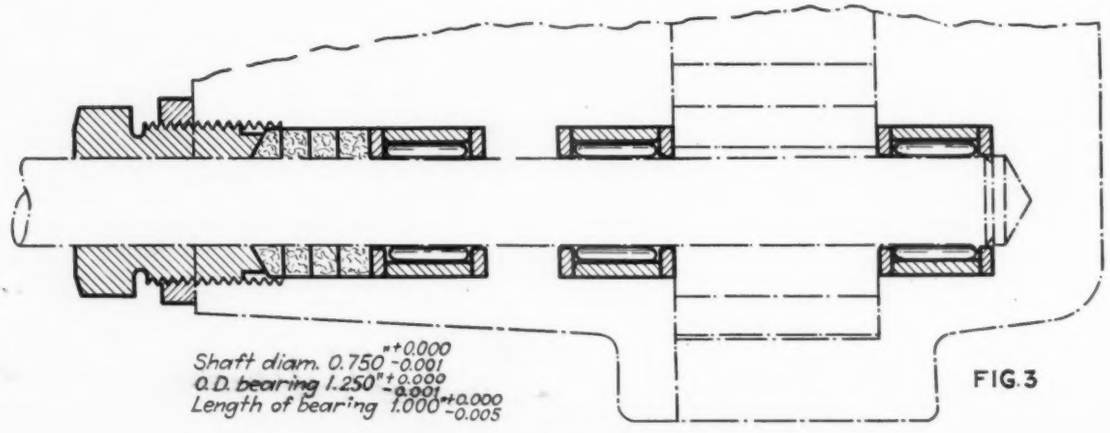


FIG.3

Small Rollers for Bearings

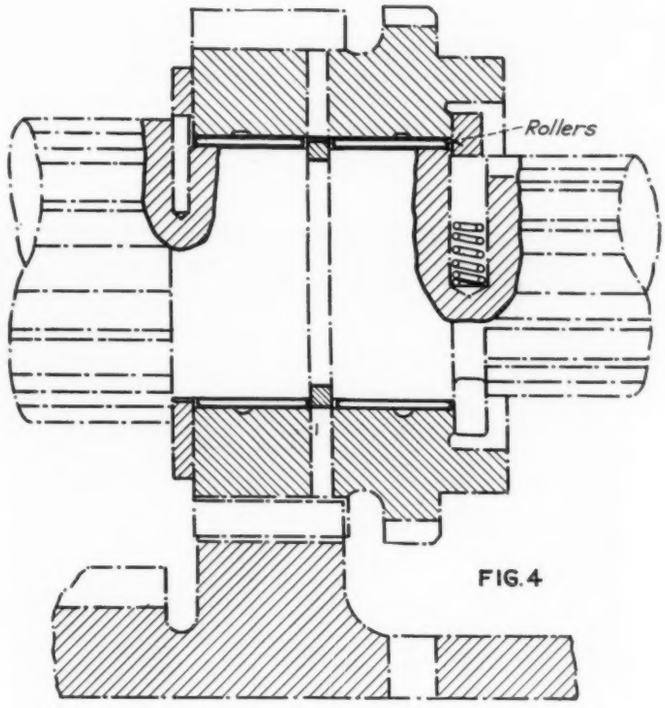


FIG. 4

Fig. 5—Needle bearing gear mounting for high-speed printing press. This bearing carries a steady load of 3,000 lb.

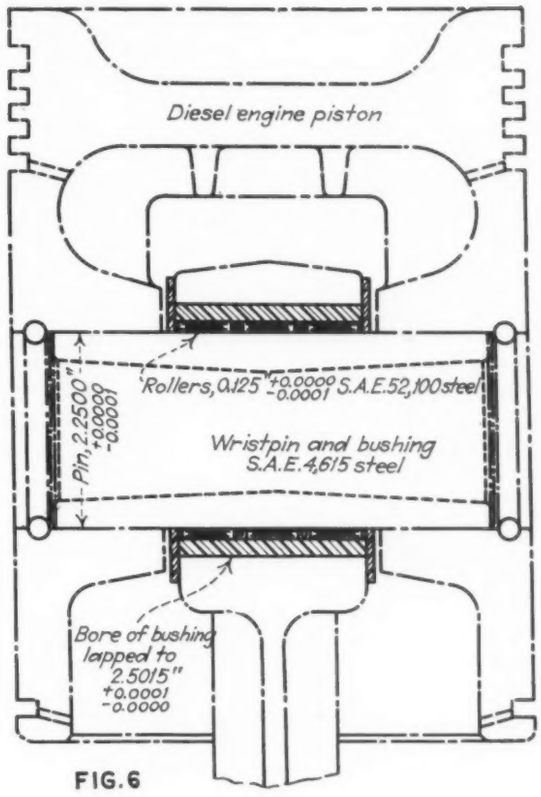

Diesel engine piston
Rollers, 0.125" +0.0000 -0.0001 S.A.E. 52,100 steel
Pin, 2.2500" +0.0000 -0.0001
Wristpin and bushing S.A.E. 4,615 steel
Bore of bushing lapped to 2.5015" +0.0001 -0.0000

FIG. 6

Fig. 6—Pin and bushing are carburized at 1650 deg. F. for 6 hr., quenched in oil, reheated to 1500 deg. F., quenched, and drawn for 5 hr. at 250 deg. F.

Fig. 7—In this bearing assembly for an automobile piston two sets of rollers, ¼ in. diameter by ½ in. long, are used. Generally, several rows of short rollers are preferable to a single set of long rollers.

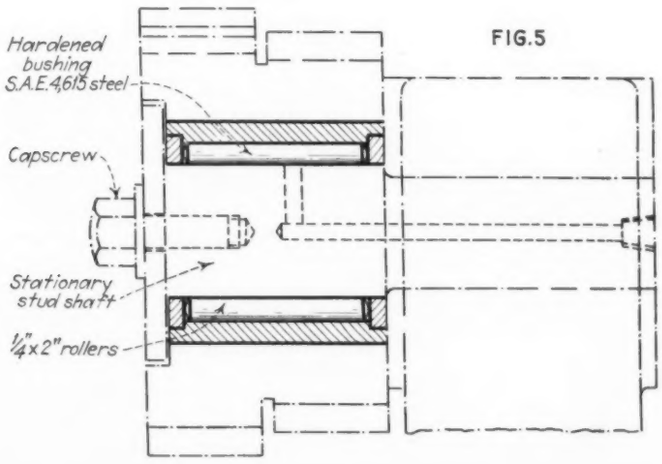


FIG. 5

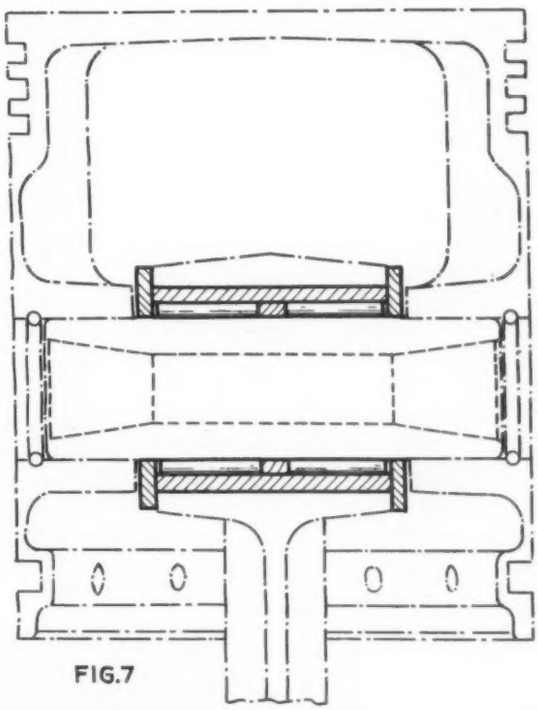


FIG. 7

Case Histories in Product Design—III

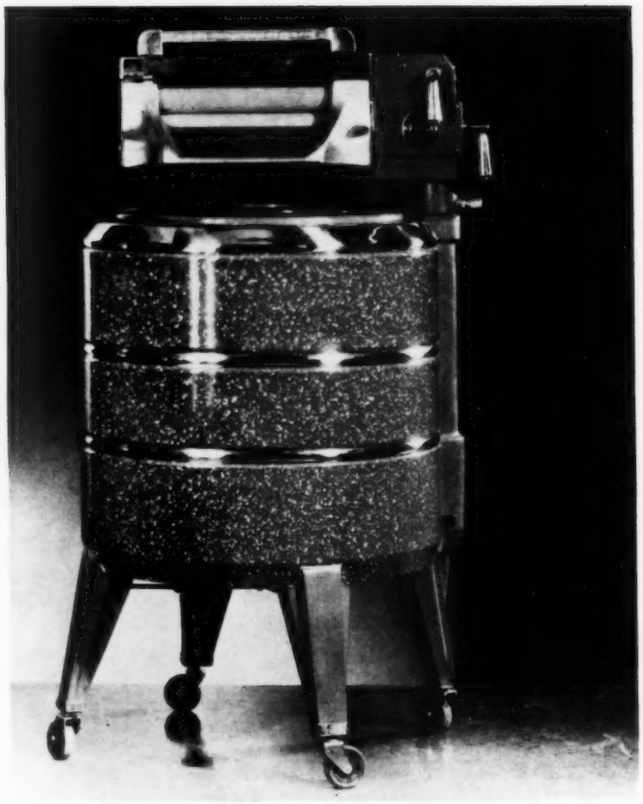
T. J. MALONEY
New Jersey Zinc Company

and

GEORGE SWITZER
Product Designer

In all of the case histories that have been presented in this series, the appearance factor has in each instance been given the greatest emphasis. It is beyond dispute that products, particularly those for the home, must have above all a pleasing appearance. Salesmen can argue dollar-value until the prospect forgets who is paying the bill. But neither the fiery oratory of a Patrick Henry nor the wheedling or cajolery of a criminal lawyer can make a goose appear like a swan.

When the household device is a piece of mechanical equipment, additional factors become equally important. In the washing machine here analyzed, centralized controls, their convenience of location, and the ease of cleaning the machine have been given particular attention. And the selling talk capitalizes these features. Good appearance plus is always hard to beat.



Controls are centralized on the wringer head. Tub and skirt for covering the motor are designed as a unit which facilitates cleaning and improves appearances

Product Case History No. 7

PRODUCT—Washing Machine.

MANUFACTURER — Sears Roebuck & Company.

ENGINEERS—Engineering Division of Sears Roebuck & Company.

ARTIST—Henry Dreyfuss.

DESCRIPTION — Sears Roebuck wanted a new washer within their present price range. The merchandising division, well aware of their customers' preferences and the absolute necessity of an attractive appearance to sales success, chose Henry Dreyfuss as design consultant to their engineering and merchandising staff. The outstanding changes resulting from this combination of talents were:

1. Instead of a multiplicity of controls located at various separated points, as is the arrangement on washers hitherto available, all controls have been centralized on the wringer head. This location of the controls was selected because it is the location most convenient for their operation. It may appear that this design feature was borrowed from the automobile dash board and radio panel. Be that as it may, it represents a distinct engineering and design feature.

2. The "skirt" or lower portion of the three-panel body is made as an integral part of the machine instead

of as a separate base and leg construction such as is typical in the older washing machines. As can be seen from the illustration, this construction not only adds to the appearance but also has the distinct sales advantage that it gives the illusion of greater washer capacity.

3. Much thought and energy was expended on giving even the gyrator a pleasing appearance. This is a sound application of intelligent designing of a working part that is constantly receiving the housewife's attention. It is true that the gyrator is out of sight most of the time. But it is a part that requires occasional cleaning. A neat design, easy to clean, is an evident advantage.

With a proper regard for safety in operation, the wringer release bar is designed so that it will require a minimum of pressure for its operation. Being a prominent part of the machine, every effort was made to give it a pleasing and harmonious shape.

4. The machine is designed so that the outer surface is entirely free of screw or boltheads. None are even visible. In so far as possible, unbroken surfaces were obtained. These design features greatly facilitate cleaning the outside of the machine.

5. A fine knowledge of material applications was required to keep the model well within the desired price range. With weight a commanding factor, the gyrator is an aluminum casting. Various zinc die-castings are used throughout. Chromium plate, enameled steel stampings and a white porcelain enameled tub are further diversifications.

SALES RESULTS—Sears Roebuck & Company are not innovators. While there is no infallibility in their choices, they are as capable as any one in meeting the consumers' wishes. This machine was put on the market less than a month ago. Already the dealer demand in the retail outlets of the company has shown a decided increase over that for the previous model. A well organized advertising campaign and a thoroughly rounded merchandising organization will soon introduce this product to the mail order clientele of the company.

One feature worthy of note is that a special medallion with the designer's name, Henry Dreyfuss, is placed on every machine. This is one of those rare instances wherein the designer is given such recognition.

▼

Sales success depends upon a combination of several factors. Advertising programs, sales organization, market conditions —each plays its part. But with all due consideration of these influences the fact still remains that sound engineering plus good appearance is hard to beat

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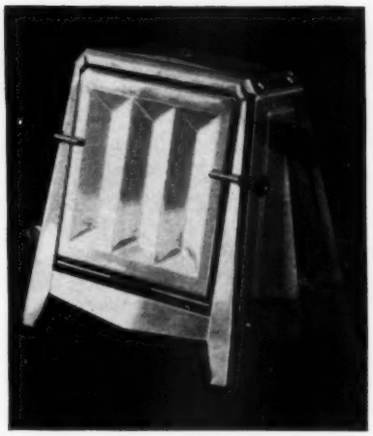
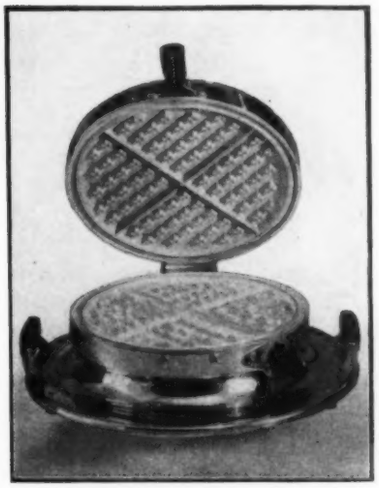
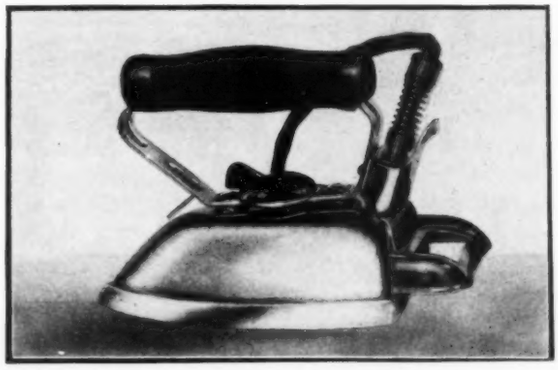






Three electrical devices for the home. Each has automatic temperature control. The control dial on the hand iron indicates the position of the pointer for the different materials to be ironed

Product Case History No. 8

PRODUCTS — Proctor Automatic Iron, Proctor Automatic Waffle Iron and Proctor Automatic Toaster.

MANUFACTURER — Proctor & Schwartz Electric Company.

ENGINEERS AND DESIGNERS —Engineering Division, Proctor & Schwartz Electric Company.

DESCRIPTION: One of the features of this hand iron is that it contains a control unit called a "fabric dial," which gives a thermostatic heat control ranging from 260 deg. F. for rayon to 525 deg. F. for linen. But the dial face is not graduated in degrees of temperature. Instead, the housewife sees on a plainly visible dial the names of the materials that can be ironed at the different control positions. The dial is simply set for artificial silk, silk, wool, cotton, linen, or whatever the material that is being

ironed at the time may happen to be.

The iron is furnished with a new type of handle made of cork with rosewood end pieces. The handle is not only attractive and of utilitarian value because of its lightness and coolness, but it is of distinct sales advantage because of its novelty. It has a tilted bale that makes the iron rest in the hand in the most comfortable position. On the metallic part of the handle, a hook is stamped out to prevent the cord from hitting the iron while in use.

An integral switch is in the body of the iron. For the cord-attached type, steel pins are used for contacts. In the unattached-cord type Monel metal is used. The body of the iron is a steel stamping, chromium plated.

The waffle iron has a glow-cone heat control which automatically indicates when the proper heat has been reached and when the waffle is done. A dual control switch not only permits turning the control on or off by hand, but also automatically regulates the heat for light or dark waffles. Simple construction is used throughout, and the lines are smartly modern but not ornate. Die-castings are used for the grid and the cam of the control unit. Body parts are composed of steel stampings finished in chromium plate.

Glow-cone type of control is also used in the toaster. In addition, a thermostatic arrangement allows for any variation in speed of toasting. The doors are so designed that when dropped after one side of the toast is finished, the toast automatically turns the doors closed and the opposite side is ready for toasting. There is no hum, burr or clicking, and the thermostatic control is located in a position to give accurate operation. Body parts have just enough modern diagonal design to gracefully accentuate the appearance, and at the same time increase the structural strength of the toaster.

SALES RESULTS—While various types of electrical appliances such as these have been on the market for the past three years, the new models came out about the first of November, 1932. Each of these products is of high-quality and high-priced. But even in spite of present conditions, they have met with sales success. This is partly because of the excellence of their design, which is obvious in each of them. Also the sales method of utilizing public utility outlets where a quality product gets a good merchandising break was unquestionably a factor. These items are outstanding examples of the success of a quality product when quality in manufacturing and the proper merchandising set-up are combined.

In the manufacture of each of these appliances, every possible production saving is made and the savings are put back into better quality and better appearance.

Product Case History No. 9

PRODUCT — American Thermos Server.

MANUFACTURER — American Thermos Bottle Company.

ENGINEERS AND ARTISTS—Design Division, American Thermos Bottle Company and Engineering Department of Doehler Die Casting Company.

This Dutch Colonial model of thermos server was selected as it harmonizes with most of the many different styles of hotel decorations

DESCRIPTION—The designing engineers of both companies had four factors to consider:

1. Appearance
2. Manufacturing Costs
3. Merchandising
4. Service

Each one of these factors played a heavy part in the design of the product. The problem was that of developing a new item—a silver-plated hot liquid server, designed primarily for the hotel trade. One of the first limitations encountered was the number of different syles permissible. To meet the modern demand for lower prices and yet to retain the same standard of quality, but one model (No. 954 is its trade name) could be permitted. To stay within this limitation of only one model and yet to be able to satisfy the demands of hotel purchasers primarily interested in designs that are harmonious with their particular type of decoration presented a difficult problem. This was further accentuated by the fact that in this country hotel decorations include everything from pseudo-Egyptian to ultra-modern styles.

After various factors had dictated the use of zinc die-castings for the body, the third problem was to evolve a design that would be neither too heavy nor too light. An idea of the emphasis that was given to weight can be gained from the fact that only 3 oz. of extra weight had condemned a previous model made of another material.

The fourth problem was to evolve a design of a leakproof and unbreakable construction.

The final result was the design as pictured here, an application of a Dutch Colonial model. From a styling viewpoint it has been highly successful. The design makes no attempt to lead the purchaser to new levels in modern design, but frankly endeavors to cater to his tastes, at least as closely as one model can do. Zinc die-castings not only made an ideal and economical body, but the dense and smooth surface took a splendid silver or chromium plate. Another advantage was that the die-castings incorporated the handle as an integral part, thereby making it possible to improve the body lines. Use of a die-casting also simplified the problem of getting leakproof and strong construction.

SALES RESULTS — With hotel buying in a demoralized state on account of present business conditions, the sales results were nevertheless gratifying. In addition to producing a larger number of sales than expected, this product served as an interesting leader, being used by salesmen to create a greater interest in their entire line.

▼ ▼ ▼

Pressure-Sensitive Elements for GAGES and INSTRUMENTS

WILLIAM R. CLENDINNING

In the design of flexible diaphragms, "capsules," bellows or Bourdon tubes such as used in pressure gages and expansion-type thermometers, the selection of a suitable material involves some unusual factors. As in instrument springs, the material must be perfectly flexible. That is, it must have no elastic hysteresis and must return to exactly its original physical condition after the load has been released. Not only must the material have had a uniform metallurgical structure when in its original condition, but the metal must not have been injured in the process of being manufactured into a diaphragm.

No fabricating shop can be expected to achieve the high degree of uniformity required of diaphragms if unusual difficulties are encountered in manufacturing. Therefore the diaphragm material must be suitably ductile for whatever manufacturing operations may be necessary. On the other hand, the first requirement is that the inherent properties of the metal be such as to make it suitable for a diaphragm. Hence, one must guard against the selection of metals that are easy to machine but deficient in primary requirements. Some degree of compromise is necessary.

In addition to possessing a uniform metallurgical structure, the material must be dense. It must be free from casting "cold shuts" in order that the fluid, be it liquid or gas, will not leak through the diaphragm walls.

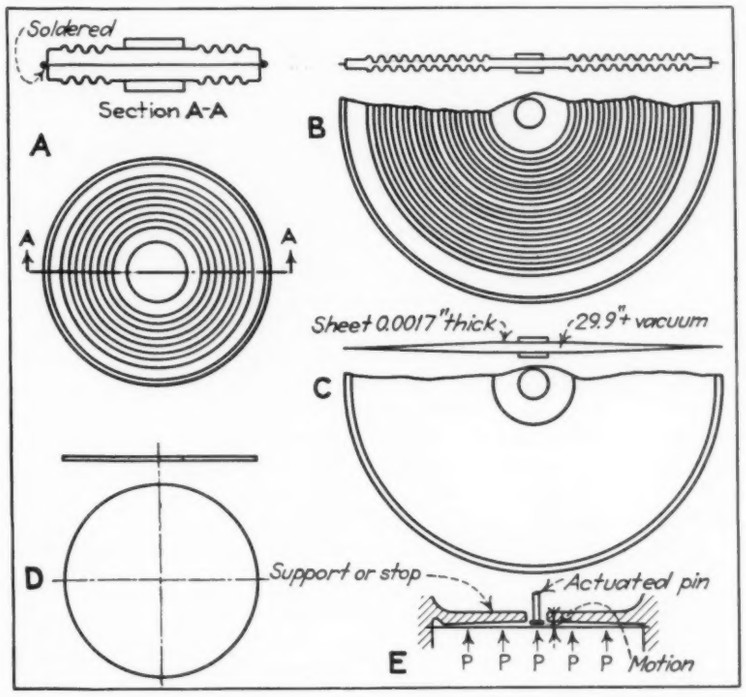


Fig. 1—Five designs of pressure-sensitive elements that operate on the principle of the flexible diaphragm. *A*—medium to high pressures, small motions. *B*—for aneroid barometers and altimeters, relatively large motions. *C*—Variation of type *B*, for extremely fine readings. *D*—Elementary disk, suitable for high pressures. *E*—Plain disk supported to resist overloads

Having selected the metal, the second phase of the problem concerns itself with the design of the unit. The unit stresses must be well below the elastic limit of the material, not only when the diaphragm is in normal operation but also when subjected to accidental overload. In addition to this, the factor of safety must be sufficiently high to meet all conditions of operation such as shock, vibration and fatigue.

Ability of the material to resist shock and vibration throughout its expected life in service depends on both the initial properties of the material and the degree to which these properties have been affected in the manufacturing operations. Fatigue cracks originate at tiny faults created in the casting process. These tiny faults become larger when the metal is worked and thereby increase the degree of stress concentration and the likelihood of fatigue failure. On account of the indeterminate character of these factors, before a material and design of diaphragm is finally adopted, samples should be tested to destruction.

Many ferrous and non-ferrous alloys have been used for diaphragms. Although high brass still leads, many designers have turned to the more "springy" types of materials such as phosphor bronze, Everdur, Adnic and others. More recently, stainless steel has been tried but not much data on the results obtained are as yet available. Another material that has been used successfully is nickel silver. According to a report by the National Advisory Committee for Aeronautics, nickel silver and phosphor bronze have been found to be the most suitable.

With reference to the accompany-

Physical Characteristics of Some Typical Alloys for Diaphragms

	Chemical Composition	Average Values for Half-Hard Sheets		
		Elastic Limit	Per Cent Elongation	Ultimate Strength
High Brass	Cu 80 Zn 20	20,000	30	40,000
Adnic.....	Cu 70 Ni 29 Sn 1	35,000	40	74,000
Everdur.....	Cu 95 Sil 4 Mn 1	65,000	15	90,000
Phosphor Bronze	Cu 95 Sn 5 P 0.20	50,000	10–15	75,000
Nickel Silver	Cu 75 Zn 5 Ni 20	35,000	15	70,000
Nickel Silver....	Cu 65 Zn 20 Ni 15	37,000	15	75,000

ing table of physical properties, it is to be remembered that all stress calculations must be based on the elastic limit, which figure is to some extent indicative of the "springy" qualities of the material. Elongation is a measure of the ductility of the material and is therefore an important factor. The figures in the table are for the half to three-quarters hard spring sheet metal, corresponding to 4 to 6 B&S numbers hard. Hardness can be increased about 20 per cent by additional rolling but the 4 to 6 numbers hard, which is equivalent to 70 to 100 Rockwell B, will usually be found to be about the correct degree of hardness if subsequent cold work is to be done on the material. For designs of the types *A* to *D* shown in Fig. 1, a softer metal may have to be used on account of the relatively larger amount of cold working to which the material will be subjected.

It is well to specify that at several steps in the fabrication of the diaphragms the hardness of the material be tested by the Rockwell or Shore instruments. This is a great help in keeping the diaphragms running true to "calibration" and also gets rid of the defective pieces in the "run" before additional labor has been wasted on them.

In the accompanying Figs. 1 and 2 are shown various types of diaphragms in common use. At *A* is shown the "capsule" type generally used for medium to high internal pressures and where small, accurate motions are required. At *B* is shown the typical diaphragm used in aneroid barometers, altimeters and similar instruments wherein a relatively large motion is required within a small range of light pressures. At *C* is shown a variation of this design as used in aviation altimeters where extremely fine readings are necessary, such as in the altimeters used for blind flying. At *D* is shown an elementary form of the typical diaphragm used in many devices such as reducing valves. These diaphragms are suitable for high pressures but are capable of giving but a small amount of motion. Sometimes the flat type of diaphragm is used in devices that might be subjected to considerable overload. At *E* is shown a method of supporting such flat diaphragms in order to give them great resistance to overloads.

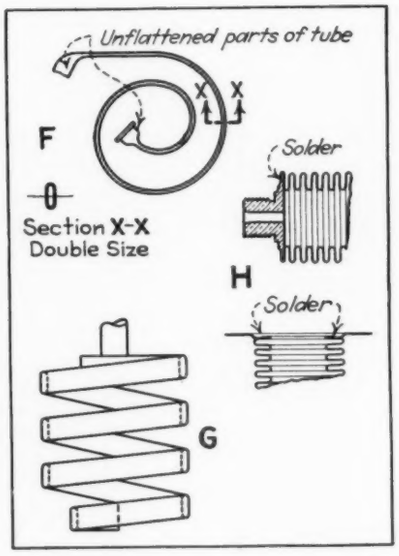


Fig. 2—At *F* is shown the Bourdon tube. *G* is a flattened tube wound on a helix. Two types of bellows construction as suggested by the Fulton Sylphon Company are shown at *H*

Referring to Fig. 2, at *H* is shown the typical bellows type which is used where large motions are required and only medium pressures are involved. The mathematics of this design is quite simple. The limitations of the design are that it cannot be made of highly springy metal and therefore cannot be used for applications wherein chemically active fluids are involved. The typical Bourdon tube, as used in steam gages and recording instruments is shown at *F*. Such tubes give a fairly uniform, though feeble movement over a wide range, can be used under the highest internal pressures and can be made of chemically resistant materials. At *G* is shown an adaptation of this design wherein the tube is in the form of a helix.

Each of the types of pressure-sensitive elements described above has its strong and its weak points. Generally speaking, any set of conditions permits a choice of one of several designs. For example, let it be assumed that a motion of 0.008 in., against a negligible amount of force, is required. The working pressure inside the diaphragm is assumed to be 100 lb. per sq.in., with a possible 100 per cent overload. Depending upon other requirements and conditions to be met, any one of the diaphragm types, *A, D, E, F, G* or *H* might be used. If, however, the required motion is 0.05 in., diaphragms of the type shown at *A, D, E, F* and *G* would require too large a diameter. The bellows type as shown at Fig. 2 *H* would be chosen for such service.

The greater number of flexible diaphragms are of the flat-plate type. The stresses in such diaphrams can be calculated on the basis of circular plates subjected to uniform pressure, the equation for which can be found in most textbooks on mechanics. However, corrugations and cold working alter so many of the assumptions that must be made in the application of these formulas that exact design calculations can be said to be impossible. Calculated stresses will be from 30 to 40 per cent in error, but this margin of error should be provided for in the factor of safety chosen. Similarly, deflections can be calculated, but here again indeterminate factors enter into the calculations, for which reason the only safe method is to determine the deflection by tests on samples.

For designs such as shown in Fig. 2 at *F* and *G*, the cause of failure would be through bursting of the tube by internal pressure. Stress calculations for this type of design can be made readily, using the familiar thin-wall tube formulas. However, the expansion or movement of these tubes with changes in pressure should be determined by experiment. For bellows as shown at *H*, manufacturers of them can furnish all necessary data for calculating deflections.

How Stresses Are Analyzed With a Polariscope

Stress analysis by transparent models is assuming greater importance. In simple language the authors explain the polariscope, how lines and fringes are interpreted and the stresses calculated. A second article will deal with stresses in shrink fits as revealed by the polariscope

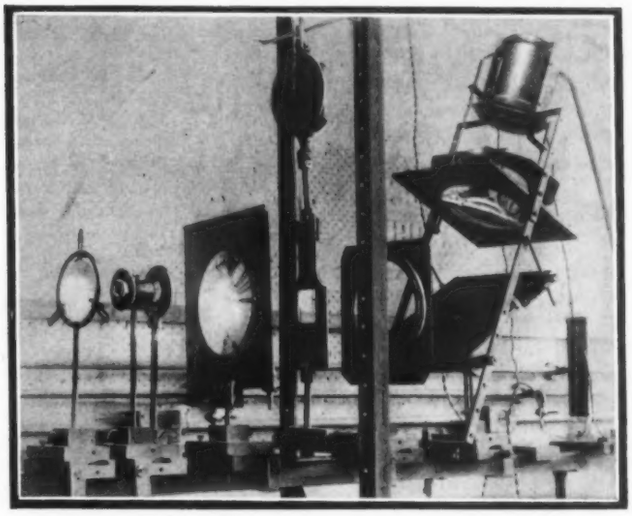


Fig. 1—Polariscope using a black mirror polarizer with a Bakelite model in the loading frame below the spring balance

The determination of the direction and intensity of elastic stresses in a transparent model is based on the fact that stresses in a transparent material retard the passage of light and alter the vibration phase of the transmitted light. Since the thickness of the material as well as the stress affects the amount of retardation, models of uniform thickness are required. In passing through any point in the model the direction of vibration of the light rays is altered to conform to the directions of the principal stresses, so that the use of polarized light, or light vibrating only in one particular direction, simplifies the determination of the stress conditions.

Models representing the structure in which the stresses are to be investigated are prepared from flat sheets of a transparent material, such as glass, celluloid or Bakelite. Although any of these materials are suitable, optical glass properly annealed, ground and polished is an ideal material for models, except that complicated forms are difficult to prepare. Celluloid is easily machined and polished and has about four times the optical sensitivity or stress retardation effect of glass, but it requires careful annealing and aging to remove internal stresses, and in addition, creep effects under comparatively low stresses limit its application to work where high accuracy is not required. Bakelite, which is commonly used for photo-elastic models, also requires careful annealing, but its optical sensitivity is about twenty times that of glass, and creep effects are much less than for celluloid.

▼

A. G. SOLAKIAN
Lecturer in Mechanical Engineering
Columbia University

and

A. H. BEYER
Professor of Civil Engineering
Columbia University

When placed in a polariscope, illustrated in Fig. 1, the transparent model is loaded to correspond to the conditions under investigation. Fig. 2 is a diagram of a polariscope incorporating a light source, filters, lenses and a polarizer to throw a large beam of polarized light over the model in the loading frame, and lenses to project an image of the model through an analyzer onto a screen. Color filters provide a monochromatic light source for effects to be photographed, but white light is used, producing colored fringes of yellow, red and green, if only visual effects are required.

A polished black mirror inclined at the proper angle to the light path has the property of reflecting only light that is vibrating in a particular plane; that is, plane polarized light. Nicol prisms also have the property of transmitting only plane polarized

light, but are expensive in the sizes required to produce a large beam of light for photo-elastic analysis. The analyzer, a second polarizer, is placed in the focus of the projected image with its axis at 90 deg. to the axis of the first polarizer; under these conditions the plane polarized light is completely extinguished. When an unloaded and stress-free model is illuminated by plane polarized light in the polariscope, no light from the model reaches the screen through the analyzer. When the model is loaded, each ray of plane polarized light is refracted by the photo-elastic effect into two rays vibrating in planes that coincide with the directions of the principal stresses at each point. Dark areas or isoclinic bands are formed over the image of the model at points where the axis of the analyzer corresponds to the direction of the principal stresses. By rotating the polarizer and analyzer together through 180 deg., the directions of the principal stresses over all parts of the model are determined.

Circular polarized light is produced from plane polarized light by the use of two quarter-wave plates of mica with their axes at 90 deg. to each other and at a 45-deg. angle to the plane of the polarized light. When circular polarized light is substituted for the plane polarized light the analyzer brings the light vibrations from a loaded model back to a common plane parallel to that of the original ray. The interference arising from the relative phase difference of the two rays produces interference fringes over the image of a loaded model, connecting areas where the intensity difference between the principal stresses is the same. As the load on the model is increased, the retarding effect of the stress causes an additional interference fringe to appear for each wave-length retardation, and the interference fringes move outward from the areas of higher stresses. Closely spaced bands indicate a region of high stress differences, so that a visual inspection of the image readily discloses the areas of maximum stress. The ability of photo-elastic analysis to show the character of stress distribution is shown in Fig. 3 for an elastic foundation supporting a load through two rollers, and in Fig. 4 for a beam under a uniform bending load.

In Fig. 3 the region of maximum stress where the fringes originate is just below the surface underneath each roller. In Fig. 4 the fringes start at the edge of the beam and travel toward the neutral axis as the load is increased. Since each successive fringe represents a uniform increase in the fiber stress, the uniform spacing of the fringes indicates that the fiber stress increases in proportion to the distance from the neutral axis.

Since the phase retardation of a given wave length of light in a given material of uniform thickness is proportional to the difference in intensity of the two principal stresses, the stress equivalent for any fringe can be calculated by subjecting a calibrating beam to a pure bending load. In Fig. 4 the stress equivalent for each fringe is 265 lb. per sq.in. for a material thickness of 0.263 in., as found by such calibration. The outer fringe —sixth from the neutral axis—represents a fiber stress of six times 265 lb. per sq.in., or 1,590 lb. per sq.in. In any model made from the same material and thickness as the calibrating beam, the stress conditions at any point on the model can be determined from the number of interference fringes that pass through the point while the load is applied.

Determination of the stress condition in any part of the model by photo-elastic analysis involves the measurement of only the coplanar stresses; that is, the two normal stresses and two shear stresses. The stresses perpendicular to the face of

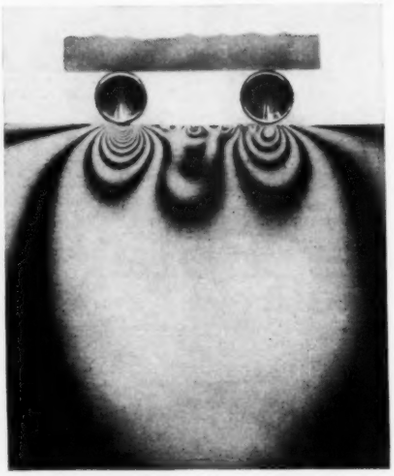


Fig. 3—Interference fringes in an elastic foundation supporting a load through rollers *A* and *B* indicating the magnitude of the differences in the principal stresses

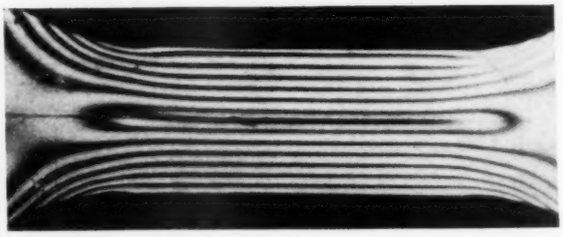


Fig. 4 — Interference fringes in a beam under a pure bending load. The equivalent stress value for each fringe as calculated from the bending load is 265 lb. per sq.in.

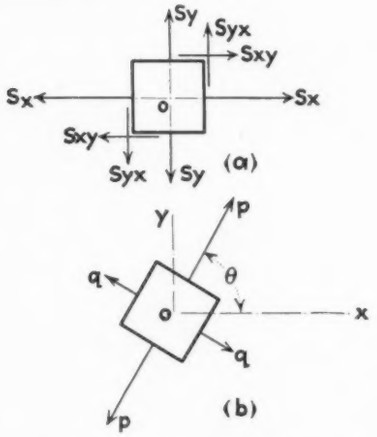
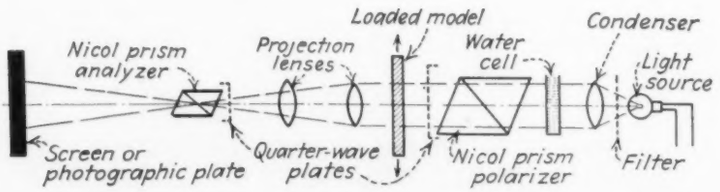


Fig. 5—Principal shear and normal stresses in an elastic model

Fig. 2—Diagram of another type of polariscope using a Nicol prism polarizer and quarter-wave plates for circular polarized light



the model can ordinarily be neglected. Fig. 5a represents the general coplanar case with the stresses resolved into normal and tangential components and referred to a set of coordinates. In Fig. 5b the same stress distribution is expressed in a simplified form in terms of the principal stresses p and q at an angle θ to the x-axis. Components parallel to the x and y axes of the principal stresses p and q can be expressed

$$P_x = p\cos^2\theta + q\sin^2\theta \quad (1)$$
$$P_y = p\sin^2\theta + q\cos^2\theta \quad (2)$$

For a given wave length of light, γ, material of a given stress retardation coefficient c, and a given thickness t, the phase retardation δ is

$$\delta = \frac{c}{\gamma}(p-q)\,t \quad (3)$$

This equation indicates that each fringe, such as shown in Fig. 4, represents an area where the difference $(p - q)$ between the two principal stresses is the same.

When the directions of the principal stresses p and q are known for any point in the model, and the numerical values for the differences $(p - q)$ are known, the magnitude of the principal stresses can be computed by a graphical integration method. The method is presented in detail in the text, "Photo-elasticity," by Coker and Filon, Cambridge University Press.

From the interference fringes produced by circular polarized light illustrated in Fig. 6 the fringe map at the left of Fig. 7 is prepared, and the value of the stress difference $(p - q)$ is determined for each fringe from a calibrating beam, such as shown in Fig. 4. The isoclinic map at the right side of Fig. 7 is traced from the isoclinics formed on the image of the model by plane polarized light as the polarizer and analyzer are rotated by 10-deg. steps. Since each isoclinic line gives the location of the stresses inclined at a given angle to the vertical, the map of the stress directions or stress trajectories is obtained by graphical construction.

The graphical integration is performed for all stress trajectories, and the horizontal and vertical components calculated from Formulas (1) and (2). The data obtained by this method for the model used is plotted for two planes in Fig. 8, showing that the 300-lb. load on the spread footing produced a maximum stress of 486 lb. per sq.in. a short distance below the top of the foundation.

Other methods of stress determination give values for the principal stresses from independent measurements of $(p - q)$ and $(p + q)$ stresses. A quartz-wedge compensator method developed by Mesnager, and a tension calibrating bar used by Coker measure the $(p - q)$ stresses at any point by counteracting the phase displacement caused by stresses in the model.

Mesnager developed a method for determining the sum of the two principal stresses from the thickness change from point to point over the model. Coker used a similar method based on measurements of the lateral extension of the model. A purely optical method used by Favre and Fabry was based on measurements of the absolute phase retardations of the two refracted rays with respect to the original ray.

For investigations requiring a moderate degree of accuracy, the lateral extensometer and quartz-compensator methods form a practical combination. For higher accuracy the optical methods of Favre and Fabry are required. For the usual engineering problem where a large number of points are investigated, and where a permanent record of the fringe pattern is desirable, the fringe method for $(p - q)$ stresses combined with the graphical integration method usually is satisfactory.

Fig. 6 — Interference fringes produced by circular polarized light indicating the magnitude of stress differences in a support for a spread footing

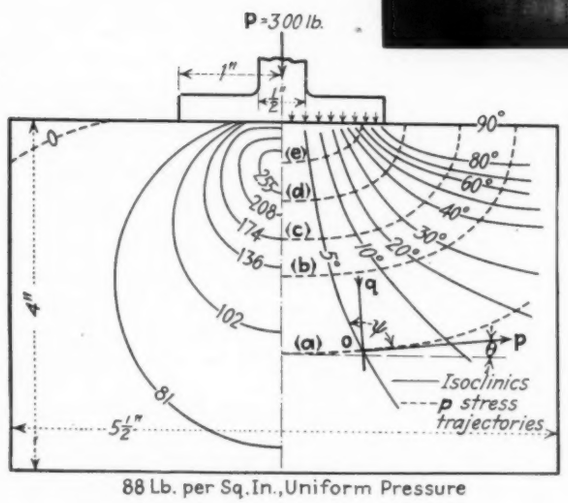


Fig. 7 — (Left) The interference fringe map obtained from the photograph Fig. 6 with stress equivalents determined from Fig. 5. (Right) Isoclinic lines traced from bands produced by plane polarized light with stress trajectories obtained graphically from the isoclinics

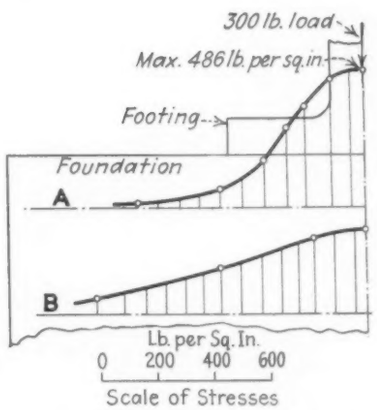


Fig. 8—Distribution of stress across two planes A and B as obtained from Fig. 7 by means of graphical integration

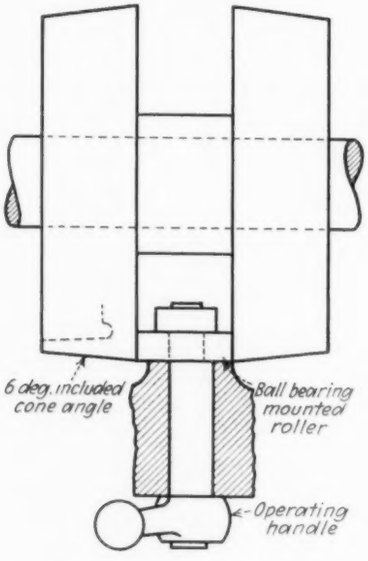
COMMUNICATION and COMMENT

Cone Clutch Shifting Mechanism

A. SMALLWOOD

In the development of a special machine, it was required to design a compact clutch of high capacity and one that would not be self-releasing. In the accompanying line drawing is shown the construction of the double-cone clutch that was designed to meet these requirements.

The ball-bearing roller is eccentrically mounted on the lever shaft, thereby giving a large lever ratio even with a small operating handle. With the roller mounted near the periphery of the cone, the first result of pressure between the roller and the cone will be to cause the cone to tilt the slight amount permitted by its clearance on the shaft. The effect of this will be that the cone will have an action analagous to a circular wedge of extremely small angle. In this way the clutch cone will not only be pressed in by axial pressure, but there will also be a rolling action that will wedge the cone into the external member of the clutch. Because of the small included angle of 6 deg., the clutch will not be self-releasing.



The eccentrically mounted roller on the lever shaft gives a high lever ratio. There is also a wedging action caused by the cone member tilting slightly

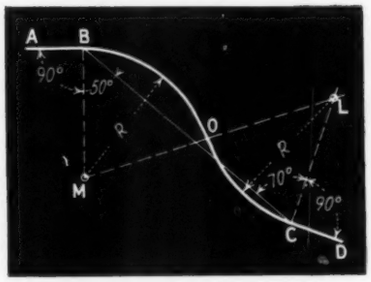
Several precautions must be taken in the design of this mechanism. Because of the small eccentricity of the roller, if the operating handle is in such a position that its weight tends to cause the clutch to engage, the pressure will be sufficient to induce rapid wear on the surface against which the roller bears. Also, slight imperfection in the surface of the roller or in the face of the clutch against which the roller bears will create undesirable vibration and chatter. A friction pad should be used on the lever shaft to hold the roller from contact when the clutch is not in engagement. A long operating handle or lever should not be used, as it would permit excessive force to be exerted against the clutch facings and might possibly rupture the outer clutch member.

A Civil Service Problem

To the Editor:

The accompanying problem was given on a civil service examination for senior draftsmen. It was found to be a difficult one to work, and I hope that some readers might be forthcoming with a simple solution. The problem has practical application, and the principles used in solving it no doubt could be used on other problems of a similar nature.

Given the lines, *AB*, *BC*, and *CD*, the line *BC* is 4 in. long, the angle *ABC* is 140 deg., and the angle *BCD* is 160 deg. It is required to construct a reverse curve between the points *B* and *C* with two arcs of equal radii, the arcs to be tangent to *AB* at *B* and to *CD* at *C*. The centers of the arcs are to be obtained graphically and the radii computed analytically.



Centers *M* and *L* are to be located graphically and the radius *R* to be computed analytically, *B* and *C* being points of tangency

—DEAN E. HOBART.

Drafting Room Procedures

To the Editor:

In this day of close margins between production cost and selling price, every effort must be made to reduce unnecessary expenses. The time spent in checking drawings naturally seems to be a logical point of attack in attempting to lower overhead expense in the engineering department.

In an aeronautical plant, the design work is carried out under the direction of a project engineer who issues general instructions for the design to one of the drafting room squad leaders. The squad leader, in turn, supervises the work of the various draftsmen assigned to the particular project. Originally, all drawings were thoroughly checked so that the checking time averaged about 35 per cent of the drafting time.

The first step toward reducing this cost was to keep a record of every

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SIGNED H. H. Smith
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R. Logan, File Clerk.

Form of requisition card for issuing blueprints

error in the work of each man as reported by the planning office or shop—60 per cent of the time required to revise the drawing being charged to the draftsman and 40 per cent to the checker. The minimum time charged was one hour. This not only served as a good basis for rating the draftsmen, but it also disclosed the fact that certain men made practically no errors of any consequence.

One of the results of this procedure was that those men who did the highest grade of work were placed in the preferred class so that in many instances their work was subject only to a general inspection, a complete detailed checking operation being omitted. Over the period of time that this system has been in operation there has been no appreciable increase in errors getting out of the drafting room and it has resulted in reducing the average checking time from 35 to 15 per cent of the total time spent on drafting.

Another appreciable saving made in the operation of this particular drafting department was in establishing a more efficient method of keeping track of tracings and blueprints taken from the files. This trouble and needless expense was practically eliminated by the use of a card file record system. A card approximately 3x5 in., sample of which is given in the accompanying illustration, was required to be filled out whenever a tracing or blueprint was issued. The filled out card was then filed according to the system of numbering the drawings, the filing being done by the clerk.

—H. L. LACKMAN
Philadelphia, Pa.

Acknowledgment

We wish to call attention to the fact that the motor frame and gear reduction housing shown on pages 83 and 84 of the March number are products of the Westinghouse Electric & Manufacturing Company which furnished the pictures for the illustrations. Through an oversight the usual courtesy line was omitted.

Additional Solutions to the Problem in Triangles

Three different typical solutions of this problem which appeared originally in the January number were given last month. Here are three more solutions, each presenting a slightly different method of attacking the problem. We regret that space does not permit publication of the many other contributions that were received in answer to this problem.

To the Editor:

The conditions are given that the three triangles are similar and also that their areas have the relationship, $A = B + C$. Hence:

$$a_1^2 = a_2^2 + a_3^2$$
$$b_1^2 = b_2^2 + b_3^2$$
$$c_1^2 = c_2^2 + c_3^2$$

These three equations represent right-angle triangles which are also similar. If the triangles can be constructed geometrically, the original triangles can be solved graphically. Two solutions are possible.

SOLUTION I

In the accompanying figure, first draw right angle triangle ABC, representing the given relation

$$a_1^2 = b_2^2 + c_3^2$$

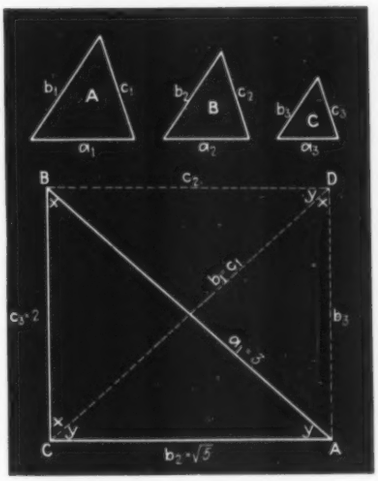
Since

$$c_3 = 2 \text{ and } a_1 = 3$$

we have

$$b_2 = \sqrt{5}$$

The horizontal line BD, the vertical line AD, and the diagonal CD are then drawn. This gives three similar and equal right triangles



CAD, DBC and BCA, the equal angles being indicated by x and y.

Thus:

$$a_1 = b_1 = c_1 = 3$$
$$a_2 = b_2 = c_2 = \sqrt{5}$$
$$a_3 = b_3 = c_3 = 2$$

SOLUTION II

The triangle ABC is drawn as in the first solution. A vertical line AD and a diagonal CD are drawn, the last being perpendicular to line AB. A horizontal line from B intersects the diagonal CD at some point E. This gives three similar right triangles CAD, EBC, and ABC, which triangles have equal angles x and y.

Hence:

$$a_1 = AB = 3$$
$$a_2 = BC = 2$$
$$a_3 = AC = \sqrt{5}$$

$$b_2 = AC_2 = \sqrt{5}$$

$$\frac{b_1}{b_2} = \frac{a_1}{a_2} = \frac{3}{2}$$

$$b_1 = CD = \frac{3\sqrt{5}}{2}$$

$$\frac{b_3}{b_3} = \frac{a_3}{a_3} = \frac{2}{\sqrt{5}}$$

$$b_3 = AD = \frac{5}{2}$$

$$c_2 = BC = 2.$$

$$\frac{c_1}{c_3} = \frac{a_1}{a_3} = \frac{3}{\sqrt{5}}$$

$$c_1 = CE = \frac{6\sqrt{5}}{5}$$

$$\frac{c_2}{c_3} = \frac{a_2}{a_3} = \frac{2}{\sqrt{5}}$$

$$c_3 = \frac{4\sqrt{5}}{5}$$

These numerical values are only calculated here to prove the work. The three triangles, *A*, *B* and *C* can be constructed directly from the drawings. Thus it is seen that there are at least two sets of triangles that fulfill the stated conditions.

—ELMER LATSHAW
Philadelphia, Pa.

To the Editor:

With the data as given in the problem and referring to the accompanying figure, let m be the ratio of corresponding sides of A and B, and n that of B and C. Then all the unknown sides will be of lengths shown in the figure. Because of similarity of the triangles the corresponding angles are equal, and the triangles have a common parallactic pole O.

As area A is equal to the sum of the area of B and C:

$$\tfrac{1}{2}a \times mb \times \sin\theta = \tfrac{1}{2}\frac{a}{m} \times b \times \sin\theta + \tfrac{1}{2}\frac{a}{mn} \times \frac{b}{n} \times \sin\theta$$

Simplifying:

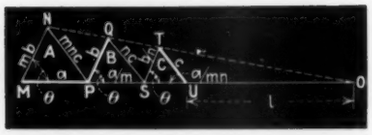
$$m^2 \times (n^2 - 1) = 1 \qquad (1)$$

It follows from the similarity of triangles OQS and OTU that:

$$\frac{QS}{TU} = \frac{OS}{OU}$$

$$n = \frac{l + \dfrac{a}{mn}}{l}$$

$$l = \frac{a}{mn\,(n-1)} \qquad (2)$$



From the similarity of triangles OQP and OTS we have:

$$\frac{QP}{TS} = \frac{OP}{OS}$$

$$n = \frac{l + \dfrac{a}{mn} + \dfrac{a}{m}}{l + \dfrac{a}{mn}}$$

$$l = \frac{\dfrac{a}{m} + \dfrac{a}{mn} - \dfrac{a}{n}}{m - 1} \qquad (3)$$

Comparing Equations (2) and (3) we get, after simplification:

$$n\,(m - n) = 0$$

Since n is not zero, m must be equal n. Then Equation (1) becomes:

$$m^4 - m^2 - 1 = 0$$

There is only one solution to this equation that is applicable to this problem.

$$m = n = \sqrt{\frac{1 + \sqrt{5}}{2}} = 1.272$$

With the ratio coefficients m and n thus found, the sides of the four triangles compute:

Triangle *A*	Triangle *B*	Triangle *G*
$MN = 2.844$	$PS = 2.358$	$TS = 1.758$
$NP = 3.236$	$QS = 2.544$	$SU = 1.854$
Area = 3.932	Area = 2.430	Area = 1.502

Check

$$3.932 = 2.430 + 1.502$$

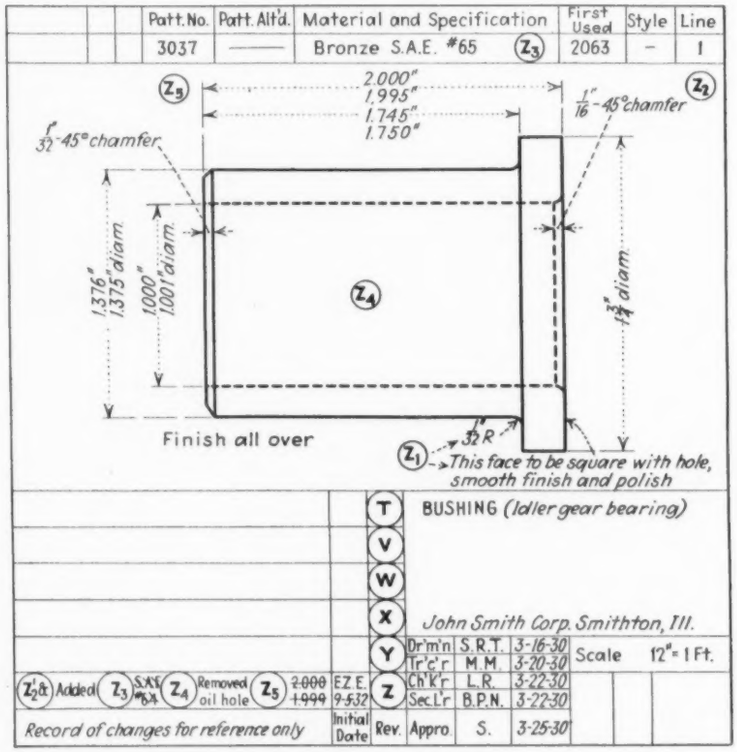
It is interesting to note that up to the tabulation just above, the values b and c of the sides given did not enter into the equations. This means that angle NOM is fixed by a, independent of the other values.

—A. R. KLIGMAN
Mattoon, Ill.

Drawing Changes

To the Editor:

A few words of warning are necessary regarding Mr. Lackman's article in the February *Product Engineering*. The method of recording drawing changes as suggested by him is not without merit. Its outstanding advantage is the fullness of description that is possible as compared with that which can be put in the small spaces near the title block. His method also


Patt. No. 3037
Patt. Alt'd. ——
Material and Specification: Bronze S.A.E. #65 (Z3)
First Used 2063
Style –
Line 1
(Z3) 2.000" 1.995" 1.745" 1.750"
1/16"-45° chamfer (Z2)
1/32"-45° chamfer
1.376" 1.375" diam.
1.000" 1.001" diam.
(Z4)
1/32" R
Finish all over
(Z1) This face to be square with hole, smooth finish and polish
T BUSHING (Idler gear bearing)
V
W
X John Smith Corp. Smithton, Ill.
Y Dr'm'n S.R.T. 3-16-30 Tr'c'r M.M. 3-20-30 Scale 12" = 1 Ft.
(Z2a) Added (Z3) S.A.E. #64 (Z4) Removed oil hole (Z5) 2.000 1.999 E.Z.E. 9-532
Z Ch'k'r L.R. 3-22-30 Sec.L'r B.P.N. 3-22-30
Record of changes for reference only
Initial Date Rev. Appro. S. 3-25-30

With this system, the complete change record is placed directly on the drawing

takes care of the recommended dispositions and of the record of authorization.

But the separation of the "Change Notice" from the drawing requires that any one wishing to know the meaning of any of the circled change references must first consult the filed change notices. Even with expert care card indexes are likely to get disarranged. Also, as the change notices must be transparent for blueprinting, the file is made up of rather flimsy sheets of paper. Blueprinting is also delayed by having to handle the slips, drawing and blueprint paper, and sometimes the notice shifts and thus covers some important figures of the drawing. Not infrequently the notices become detached from the tracings and even get lost.

A system of recording changes on drawings is illustrated herewith. The circles around the symbols are made especially heavy so that they can be seen readily. Changes made at one time are given the same reference letter, with a different subscript number for each change. Before the change is actually made on the drawing it is entered in the revision table. With this system a complete record of changes is put on the drawing.

—W. S. Brown
Auburn, New York

Daily Job Tickets

J. S. Archer

Engineering costs are now being treated as other manufacturing costs in that they are being charged against the product. In a number of plants time clocks are used for recording engineering time, but there is an inherent aversion to their use among engineering personnel. The same purpose can be accomplished by letting the individual write in his time on a daily job ticket, a separate ticket being used for each job. Some sort of ticket must be provided anyhow, in order to identify the job. A daily job ticket as used by one company is shown here. This form tells the story and serves the same purpose as a time clock without the inconvenience of the latter.

	AP-3056 (SCHEDULE AND JOB ORDER NO.)				
7364 (CHECK NO.)	Smith, John (NAME)			5.76 (PAY RATE)	
Frame & Support (NAME OF PART)				Radio Table XP04-A Plane (OPERATION)	
STOP 4.30	10-31-32		START 8:00	1 Fr & 1 Sup (NO PIECES WORKED ON)	
				34 (OPERATION NO.)	
	HOURS	TENTHS	$	CENTS	
REGULAR	8		5	76	FINISHED ☐
EXTRA					NOT FINISHED ☒
TOTAL	8		5	76	Lewis Jones (SUPERVISOR)

Sample of job ticket

To an engineering executive the job ticket system of keeping account of engineering time is usually a revelation as to the value of the various men in his department. The man who produces quality through continual redesign, recheck, and consultation with others, soon stands revealed in comparison to the man who gets an assignment, digs in, and bats it out in satisfactory form and time.

DEFLECTIONS

ILLUMINATING FACTS

Some engineers of the Westinghouse Lamp Company, who evidently like to do figuring, have calculated that it would require all of the 350 million lamps sold in this country in one year to duplicate or produce a light intensity equivalent to sunlight over one square mile of the earth's surface. This same number of lamps could produce "moonlight" over an area of 400,000 square miles. Reduced to smaller units, it would require more than 12 average incandescent lamps per square foot of the earth's surface to produce artificial sunlight.

GLUE IN SHEET FORM

Engineers who have wrestled with the problem of warpage in thin plywood may find an answer in a new dry, sheeted, ready-to-use glue just announced by Tego Gluefilm, Inc. The material, which is evidently a phenolic resinoid, comes in sheets of almost any size in a standard thickness of 0.005 in. Gluing process consists in placing sheet between wood plies and applying heat and pressure. It is also claimed that satisfactory joints can be made between wood and metal.

SUPER-GLASS

Whether or not they have a common progenitor, two new superplate glasses are coming into use almost simultaneously in England and Germany. The English glass known as "Armour-Plate" has the transparency and weathering properties of ordinary glass, yet will stand a dead load 3 to 4 times as great. A steel ball which will break ordinary plate-glass when dropped from a height of 20 in. has to be taken to a height of at least 12 ft. before it will break a piece of the new material. When it does break, it shatters into tiny fragments too small to cause anything but superficial scratches. It will bend 3 to 4 times as far as ordinary glass before breaking. Molten lead at a temperature of 620 deg. F. will not break it, and at 15 deg. below zero F., or 47 deg. of frost, it has resisted a blow just as well as at ordinary temperatures. The German glass known as "Sekurit" has similar mechanical properties.

DEAD SILENCE

All padded cells are not for lunatics. In the laboratories of the General Electric Company is a cell padded with layer on layer of sound-absorbing materials that completely isolate the room from outside noises. In this room are conducted experiments to determine by means of noise meters the amount and type of noise produced by motors, fans and other equipment.

FORM AND COLOR IN A NEW RÔLE

According to studies, certain patterns and colors of floor coverings in passenger elevators tend to induce people to step toward the rear of the cab. There are definite psychological reasons for this, which lead to the thought of the possibility of other applications of these same principles. Facetiously, cash register keys of certain shapes and colors might be adopted to intensify the urge to punch them, while lubricating fittings might be so patterned that they will "cry out" for attention. Conversely, mechanical devices for the home might be studied to give an appearance that will deter the ever-present family tinkerer.

NEWS

Important Action Taken on A.S.T.M. Specifications

Much progress was made toward the adoption of standard specifications for rivet steel, springs, alloy-steel castings, steel for fusion welding, wrought iron bars and plates, gray iron castings and sheet high brass at the spring meetings of the committees of the American Society for Testing Materials held in New York City, March 6-10.

The committee on steel recommended that a special committee be appointed to study the possibility of combining all rivet specifications into one specification; recommended approval of a new tentative specification for heat-treated carbon-steel elliptical springs; recommended for adoption as standard the Tentative Specifications for Lap-Welded Iron Boiler Tubes; approval of new tentative specifications for alloy steel castings for structural purposes; approval of the inclusion in the book of standards and book of tentative standards of a list of specifications for steels suitable for fusion welding; and recommended the approval of extensive revisions in the standard specifications for lap-welded and seamless steel pipe for high temperature service.

The committee on wrought iron recommended that the tentative revision in the specifications for staybolt, engine bolt and extra-refined wrought iron bars be advanced to standard. These revisions, issued in 1931, include a change from 48,000-54,000 lb. per sq.in. to 48,000-53,000 lb. per sq.in. in the tensile strength of sections 1¼ sq.in. or less in area.

It was voted by the committee on gray iron castings to recommend the adoption of the tentative specifications for gray iron castings (A48-32T) as standard. There are the specifications that were formulated by Committee A-3 with the cooperation of the Gray Iron Institute and were approved for publication as tentative at the June, 1932, meeting of the society. These specifications supersede all previously existing individual specifications and include classifications ranging from 20,000 to 60,000 lb. per sq.in. tensile strength.

Specifications covering high-strength silicon-copper alloys will be given consideration by the sub-committee on wrought metals and alloys. The committee also approved for advancement to standards, revisions in the specifications for sheet high brass. These revised specifications will cover two grades instead of one as formerly, and two additional tempers.

Joint Symposium on Cast Iron

At the annual meeting of the A.S.T.M. at Chicago, the committee on cast iron, in cooperation with the American Foundrymen's Association, will present a joint symposium on cast iron on Monday, June 26. The American Foundrymen's Association and the American Society for Testing Materials are also preparing a joint symposium on specifications and testing of cast iron which will be given on Friday, June 23, at the meeting of the American Foundrymen's Association, also at Chicago.

"Wax-Operated" Switches Developed in Britain

Ordinarily, small replaceable type fuses are not practical for safeguarding small motors against overheating. One method for such protection is through the use of a thermal switch.

Aiming to provide similar motor protection, the Indiarubber Gutta Percha and Telegraph Works Company, Ltd., of Great Britain, has developed two types of "wax-operated" switches. In one type, wax in the form of a rod of small diameter is electrolytically coated with metal. Thickness of the coating gives a sectional area of 0.000018 sq.in., equivalent to a No. 40 gage wire. But the mechanical strength of this "tube" is such that it must have the support of the wax. When overheating causes the wax to melt, the metallic tube breaks, thus interrupting the circuit.

For the mechanical operation of a switch, a helical spring heating coil is placed inside a cylinder which is then filled with wax. When hardened, the wax holds the spring in position. In conjunction with this is a switch with a catch mechanism that is actuated by the helical spring. When heated, the wax softens and permits the helical spring to trip the switch.

Navigation Aids Demonstrated

Before the New York Electrical Society on March 16, Dr. H. G. Dorsey, of the U. S. Coast and Geodetic Survey, described and demonstrated modern aids to navigation. These included the photo cells for turning on lighthouses and beacons automatically as the natural light diminishes to a given intensity; radio direction finders; the fathometer, a sonic depth sounding device; a device using infra-red rays to detect icebergs in fog or darkness; and a new automatic SOS transmitter. Infra-red rays will penetrate fog and reflect from such obstructons as icebergs thus providing a means of obtaining warning of this very real navigation peril. The fathometer gives continuous readings of water depth which are plotted on a paper roll and can be compared with a profile chart to determine the location of the ship as it approaches land. Dr. Dorsey also demonstrated a talking fog siren, in use abroad, that identifies its position and dispatches audible and radio signals by which the mariner can determine his distance from the source.

New Uses for Cast Iron

When welding began to make appreciable inroads on the foundry business, there was an immediate reawakening in the latter. Remarkable advances were made in foundry technique, and the quality of the product greatly improved. As a result, numerous designs that had changed from casting to welding reverted back to cast construction. Similarly, cast iron found itself losing its markets to alloys. The gray iron foundry industry quickly put forth great efforts to improve the physical and

chemical properties of its product. The superiority of gray iron castings of today over those of ten years ago is well known.

In an address on March 22 before the Gray Iron Institute, of which he is manager, Arthur J. Tuscany cited numerous new applications of gray iron castings that have resulted from the improved strength, finish, texture, resistance to heat, or other properties of the material. Of particular interest were such items as refrigerator coils with cast-on fins, developed to replace pipe coils; gray iron camshafts; the return of cast iron brake drums in the automotive industry; and the development of gray iron crankshafts to be used in automobile engines. The return of the use of cast iron for kitchen equipment was also mentioned, it being explained that enameling and chromium plating is being used to improve appearances so as to make the cast products acceptable. This last illustrates how developments in one field, in this instance surface finishing, open the way for radical changes in other fields.

Case School Conference Postponed

On account of the unsettled state of affairs, it was deemed advisable to postpone the conference on "Re-Engineering for Economical Manufacture," which was scheduled to be held at the Case School of Applied Science, Cleveland, Ohio, March 22-24. It is expected that this conference will be held later with substantially the same program.

Aluminum Window Panes Misrepresented

Various technical publications, and the German press in particular, have been reporting that transparent aluminum glass has been manufactured in Germany. *Product Engineering* has investigated these reports and, through the United States Department of Commerce and its Washington correspondent, finds that the reported development of a process for producing a transparent substance from aluminum has been misrepresented.

It appears that while the press reports of the actual manufacture of glass from aluminum are not well founded, at least there is a theoretical possibility for the production of fully transparent sheets of aluminum oxide. The process in question is controlled in Germany by the Vereinigte Aluminum Werke A.G. of Lauta. It is understood that this company is steadily pursuing scientific experimental work regarding the development and utilization of aluminum oxide in transparent form. To date, however, this development has not reached the commercial stage.

MEETINGS

American Welding Society—Annual meeting, Apr. 27-28, New York, N. Y. Miss M. M. Kelly, secretary, 29 W. 39th St., New York, N. Y.

American Gear Manufacturers Association—Annual meeting, May 4-6. Penn Lincoln Hotel, Wilkinsburg, Pa. J. S. McQuiston, managing secretary, First National Bank Bldg., Wilkinsburg, Pa.

American Society for Testing Materials—Annual meeting, Chicago, Ill., June 26-30. R. E. Hess, assistant secretary, 1315 Spruce St., Philadelphia, Pa.

American Society of Mechanical Engineers — Semi-annual meeting, June 26-29, Hotel Stevens, Chicago, Ill. Calvin W. Rice, secretary, 29 West 39th St., New York, N. Y.

American Institute of Electrical Engineers — Semi-annual meeting, June 26-30, Chicago, Ill. H. H. Henline, secretary, 33 West 39th St., New York.

EXHIBITIONS

International Association of Blue Print and Allied Industries—Annual meeting and exhibition of equipment, May 29-30, Buffalo, N. Y. R. Bloomfield, secretary, 161 Washington St., New York, N. Y.

Sixth Midwest Engineering and Power Exposition—Coliseum, Chicago, Ill., during "Engineering Week" of Century of Progress Exposition, June 25-30. Headquarters, 308 W. Washington St., Chicago, Ill.

Second American Exposition of Brewing Machinery, Materials and Products—Auditorium Hotel, Chicago, Ill., Sept. 31 to Oct. 1. J. R. Nicholson, 55 W. 42nd St., New York, N. Y., secretary, Master Brewers Association.

Vibration as a Fire Hazard

Recently a fire at the Burlington, N. J., station of the Public Service Gas & Electric Company did considerable damage to one of the turbine units. Only quick action prevented the fire from spreading. All the evidence uncovered in an investigation of the cause of the fire indicated that one of the lubricating-oil pipes on the turbine had broken.

Although the pipes had been properly designed for the static load involved, vibrations from the rotor introduced the factor of fatigue. The fatigue strength or endurance limit of the material being much lower than its yield point, failure caused by the vibrations was bound to occur sooner or later.

This is not the first instance wherein vibrations have caused failures of such a nature. It emphasizes not only the importance of minimizing vibrations but also illustrates the entirely unexpected failures that may occur if this factor is not given proper consideration.

White-Metal Bearing Alloys

Some interesting facts concerning the wear resistance and other mechanical properties of white-metal bearing alloys were established in a series of tests conducted by the Bureau of Standards. The alloys tested included two tin-base and eight lead-base alloys, and one alloy of cadmium and zinc.

According to the test results, tin-base alloys showed higher resistance to wear and in most cases had higher Izod impact values at the temperature tested than did the lead-base alloys. However, the tin-base alloys showed a lower resistance to pounding than did the lead-base and cadmium-zinc alloys. The hardness numbers and compressive properties of the tin-base alloys were found to be lower than those for the cadmium-zinc alloys.

It was also established that increased hardness of lead alloys can be obtained either by the addition of calcium and barium or by the additions of calcium, sodium, potassium, and lithium. With reference to the lead-antimony-tin alloys, their mechanical properties in most cases increased with the tin content.

NEW MATERIALS and PARTS

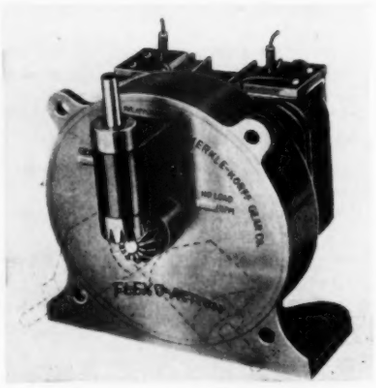
Haveg

Is composed of acid-resisting asbestos and phenol-formaldehyde type resin molded into a solid homogeneous mass by heat and pressure. Physical characteristics: Specific gravity, 1.6; compressive strength, 10,400 lb. per sq.in.; tensile strength, 5,600 lb. per sq.in. Will not crack from sudden exposure to temperature changes (can be used up to 265 deg. F.); low heat conductivity; completely resistant to hydrochloric acid under any conditions of temperature and concentration; completely resistant to sulphuric acid up to 50 per cent concentration, and formic acid up to 40 per cent concentration.

Haveg can be molded into solid, seamless, and jointless round or rectangular tanks of any size up to 10 ft. diameter and 10 ft. high. Has been used in Germany for a multitude of uses wherein chemical corrosion is a problem such as in kneading and mixing machines, filter cells, drying equipment, ventilators, agitators as shown in illustration, pipes and fittings, valves and cocks, pump parts. Owing to the intricate nature of the manufacturing process, all work must be done at the plant of the supplier. Haveg Corp., Newark, Del.

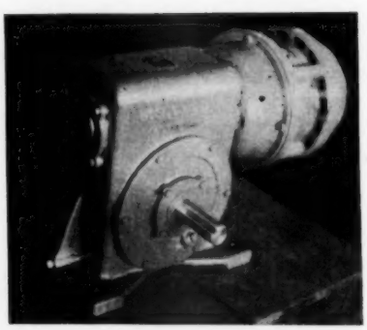
Merkle-Korff Reversible Reduction Unit

For low torque requirements, consists of assembly with two-pole reversible motor. Designed to start, stop and run in either direction under control of simplest possible switching means; 115 volts, 60 cycle considered standard. Special units available for any voltage from 15 to 230 and for any frequency from 25 to 60 cycle. Available with either horizontal or right angle drive. Over-all dimensions: Depth, $3\frac{7}{16}$ in.; height, $3\frac{5}{16}$ in.; width, $3\frac{11}{16}$ in. Merkle-Korff Gear Co., 213 N. Morgan St. Chicago, Ill.



Boston Motorized Worm Gear Speed Reducer

Has the worm and the motor shaft made integral to insure quietness and positive alignment. All models equipped with General Electric motors, but other makes of motors may be used economically where the complete assembly is produced in quantities. Available in various sizes, horsepowers, and speeds. Boston Gear Works, Inc., North Quincy, Mass.



"Genuine Detroit" Solenoid Valves

Designed for use where desirable to control electrically the flow of oil, gas, water, air or low pressure steam refrigerants. Solenoid coil is vacuum impregnated to resist moisture. Tested to withstand 1500 volts between coil and

body. Each coil consumes approximately 7 watts. Current may be left on indefinitely without danger of overheating. All types are so constructed that coil may be changed without removing valve from the line. Detroit Lubricator Co., Trumbull, Lincoln, Marquette & Viaduct, Detroit, Mich.

"Svea Metal" for Vacuum-Tubes

This metal is declared to have many superior properties for use in electronic tubes as electrodes, plates, getter cups, screens, lead-ins, support wires, etc. As compared with nickel, advantages claimed are reduced bombardment required; longer life because of less ionization by collision; higher heat resistance; lighter weight; close approach to glass in coefficient of expansion; easily weldable to nickel or copper; can be rolled,

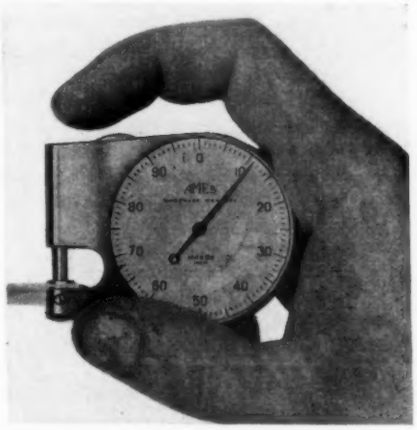
worked or processed in any way. Properties as set forth by its producers are:

Electrical resistance, microhms per cm. cube	10.2
Melting point, Centigrade	1535
Specific heat	1150
Watt loss per kilogram at 60 cycles	0.070
Tensile strength, lb. per sq.in.	44,000
Weight per ft. 0.005x6-in. strip.	0.102
Specific gravity	7.86
Permeability, initial	180

Swedish Iron & Steel Corp., 17 Battery Place, New York, N. Y.

Ames Thickness Measure

Designed to fit vest pocket like thin model watch. Dial graduated in thousandths. Chart stamped on back of gage for determining nearest fractional equivalent. Movement of one finger turning operating wheel opens anvils to admit work being measured. Built of non-rusting metal. B. C. Ames Co., Waltham, Mass.

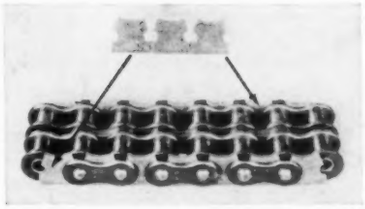


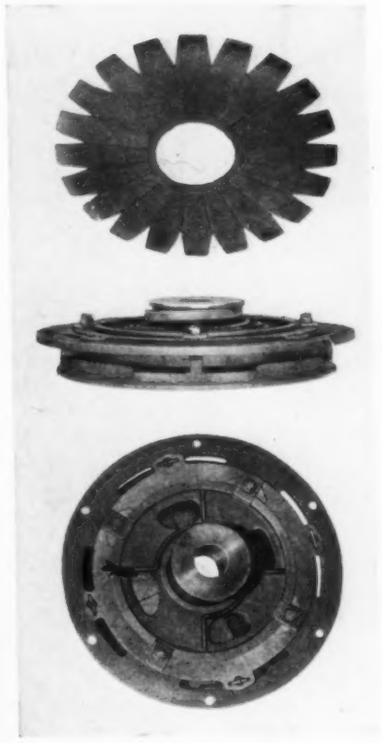
Electrunite Welded Boiler Tubes

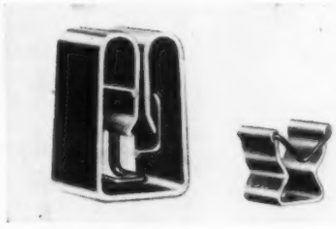
Electric resistance welded boiler tubes made from continuous steel strip, formed and electric welded under pressure. Tubes normalized and tested. Available in all sizes up to 5 in. O.D. in copper bearing, nickel steel and Toncan iron. Claimed to have uniform diameter and wall thickness, and surface finish equal to strip steel. Steel & Tubes, Inc., 224 E. 131st St., Cleveland, Ohio.

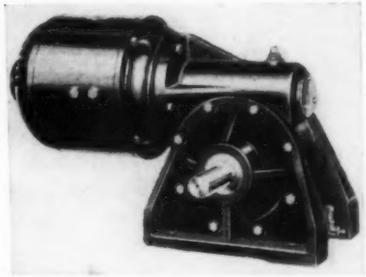
Square D Positive Pressure Fuse Clips

Have been a feature of various Square D safety switches, lighting panels and distribution panels during the past year. Claimed to lower heating at contact between clip and fuse by 60 per cent. Clip itself made of pure copper. Reinforcing steel spring is rustless to insure long contact life and positive automatic gripping of the fuse. In 30 and 60 amp. size clips, spring is imbedded in copper clip so that it cannot work loose. On larger size jaws reinforcing member is held by mounting bolt of jaw. Accompanying illustration shows two types. Square D Co., Detroit, Mich.









Whitney Anti-Back-Bend Chain

Has small wedge-like elements assembled into standard chain at every pitch to prevent back bend. Interchangeable with standard chain contacting sprockets on one chain face. Claimed that stiff back chain reduces vibration and whip, and life of chain is materially increased because of the supporting action of the check links. Whitney Mfg. Co., Hartford, Conn.

Lipe Heavy Duty Automotive Clutch

Features 20 interlocked pressure levers so arranged that centrifugal force acting on them assists the clutch spring when clutch is engaged, and opposes or weakens spring when clutch is disengaged. This is claimed to result in smooth engagement and automatic compensation for loss of spring pressure resulting from wear of facings. Sizes and recommended ratings follow:

Nominal Size	In. Lb. Torque Recommended	Hp. at 1000 R.p.m.
11 in.	2000	32
12 in.	2400	39
13 in.	3200	51
14 in.	4200	67

Clutches may be calibrated to hold full release at any speed from 2300 r.p.m. and up to full engine speed; also the unit pressure will build up in full engagement to from 50 per cent to 85 per cent thus augmenting the spring pressure.

The 11-in. clutch may be calibrated so as to hold out at any speed from 2,900 r.p.m. and up to full engine speed. The spring pressure is increased from 40 per cent to 80 per cent by centrifugal action acting on the levers of this clutch. W. C. Lipe, Inc., Syracuse, N. Y.

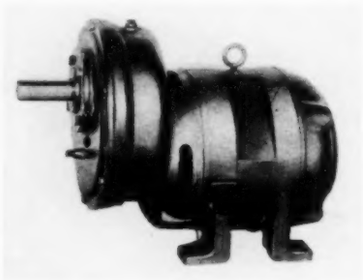
Janette RW-3 and RW-4 Speed Reducers

Are, except for size, identical in appearance. Between these two units it is possible to obtain motor horsepowers of from ½ to 5 hp. in polyphase, or d.c. motor speeds of 1,140, 860, 690 and 575. Twelve standard ratios ranging from 90:1 to 8:1. Units consist of ball bearing motor bolted directly to gear housing, the worm being on extended motor shaft, the outer end of which is supported by a third ball bearing. Slow-speed shaft is supported by two tapered roller bearings. Worm is of hardened

and polished steel; gear is special bronze. Obtainable in eight different mounting positions. Janette Mfg. Co., 556 W. Monroe St., Chicago, Ill.

James Motorized Speed Reducers

Wherein speed reducer and motor are combined as a single unit. Available in ratings from ½ to 20 hp. with wide range of ratios and speeds. Gears are of continuous-tooth herringbone construction mounted on anti-friction bearings running in bath of oil. D. O. James Mfg. Co., 1114 W. Monroe St., Chicago, Ill.



No-Fray Rubber-Sheathed Lamp Cord

For use where textile covered cord is unsuitable. Carries the underwriters' 5-ft. safety label. Claimed that all-rubber construction gives longer life,

and cord does not fray, break, or pick up dust and dirt. Available in brown or black and with Belden soft rubber plugs to match. Belden Mfg. Co., 4689 W. Van Buren St., Chicago, Ill.

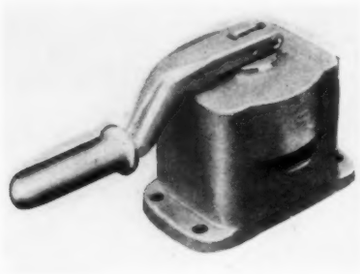
Agastat Time Delay Relay

For opening or closing a circuit after a predetermined time interval. A solenoid magnet moves a shaft carrying a contact member and restrained by a timing device, governed by the transfer of gas between two chambers connected to each other through a small passage controlled by a check valve. Time delay, controlled by the gas passage between chambers is adjusted at the factory. The time range is from one second to 30 min. Relay coils wound for voltages up to 230 d.c., and 220 a.c., 25 or 60 cycle. Silver-to-silver contacts rated at 2 amp. d.c. and 6 amp. a.c. Over-all dimensions 2¾x2¾x4 1/16 in. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Agastat, a Pneumatic Time Delay Relay

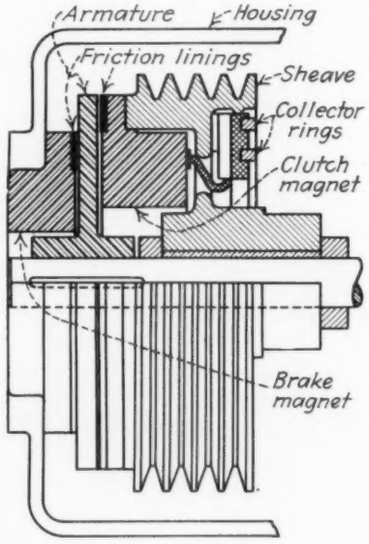
Q-C Sav-Air Control Valve

With body of valve bronze and all operating parts rust-proof material. No joints or gaskets to leak. Valves are poppet-type, claimed to be positively leak-proof. Available in sizes from ¼ in. to 1 in. Q-C Engineering Products, 1310 Maple St., Detroit, Mich.



Magnetic Clutch and Brake Unit

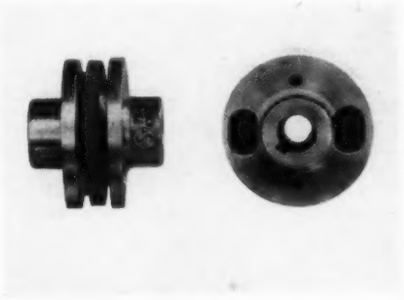
Provides both clutch and brake action for machine tool and screw machine spindles to eliminate belt shifting and manual stopping. Armature, slideably keyed to shaft, is used for clutching and braking. Collector rings are mounted



within sheave to conserve space. Clutch diameter is 10 in., with torque rating of 1,000 in.-lb.; brake diameter 8 in., torque rating, 350 in.-lb. Magnetic Mfg. Co., Milwaukee, Wis.

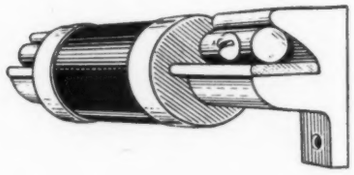
Small Series Flexoid Coupling

Flexible fabric disks are connected to aluminum alloy flanges with socket head setscrews. No metal-to-metal contact. Claimed to be suitable for reversing and automatic starting because of reduced backlash. Available in two diameters, 2⅝ in. rated at 1 hp. at 1,800; 3⅛ in. rated at 3 hp. at 1,800. Smith Power Transmission Co., Penton Bldg., Cleveland, Ohio.



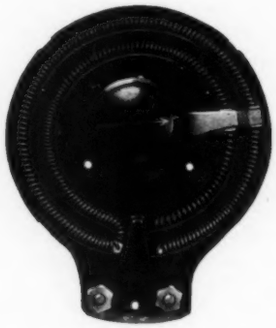
Trumbull Vystipe Fuse Clamp

Available for 30 amp., 230 volt "R.B." switch. Claimed that pressure clamp by compelling proper fuse alignment and contact reduces heating at fuse terminals—prevents premature blowing of fuses. Entire line of "R.B." switches, 30-800 amp. capacity are now available with Vystipe clamps. Trumbull Electric Mfg. Co., Plainville, Conn.



Ward Leonard Coil Type Rheostat

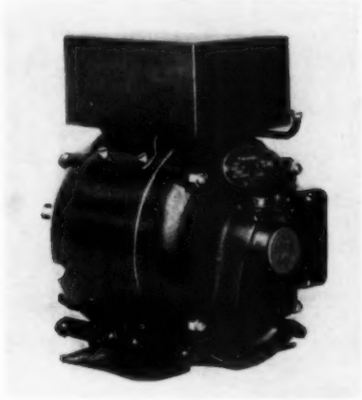
For applications requiring fine continuous adjustment. Extremely shallow depth is distinct advantage where space



is limited. Coiled wire resistance element of low-temperature coefficient of resistivity set in concentric grooves cast in refractory base. Plate and wire coated with powdered glassy enamel, and fired at red heat, to prevent shifting of resistance wire with adjustment of contact shoes. May be adapted to steel panel mounting without use of insulating bushings or washers. Ventilated inclosure can be provided for protection of live parts. Available in values of resistance from 1 to 350 ohms. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Improved Capacitor Motor

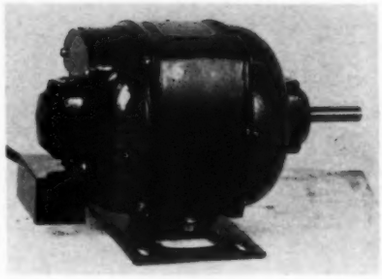
For refrigerator applications. Has drip-proof end flanges, a terminal box with three terminals, one of which is a dummy. Terminal cover is reversible and has lead clamps eliminating lead anchors. The direction of rotation can be changed by interchanging the motor leads at the terminals. Longitudinal movement of the rotor is automatically cushioned. Bearings changed to double the oil capacity and smaller capacitor used. Steel spring base furnishes a resilient mounting. General Electric Co., Schenectady, N. Y.



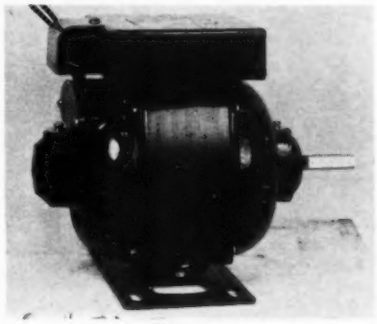
Leland Type KS and KL Split-Phase Motors

Type KS recommended on any application requiring motor of quiet operating characteristics, normal torques, and light starting torque such as for ventilating equipment, oil burners, and fans. Form KSA is rigid mounting and KSAT has a cradle that is rubber spring mounted.

Type KL recommended for oil burners, stokers, or refrigerator applications where ultra-quiet operating characteristics and moderately high torques are required. In this type, the box containing electrolytic condenser is fastened to top of motor stator. Noise from vibration is claimed to have been completely eliminated. Start to run changeover accomplished by specially designed mechanical switch similar to that used on Type K capacitor. Available in $\frac{1}{8}$, $\frac{1}{6}$ and $\frac{1}{4}$ hp. rating. Leland Electric Co., 1501 Webster St., Dayton, Ohio.



Type KS Leland motor



Type KL Leland motor

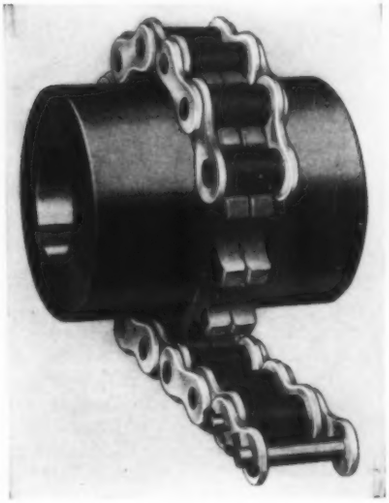
Edgerton Stroboscope

Permits intermittent observation of a cyclic or constantly recurring motion so that the apparent speed of the motion is reduced or stopped. Type 548-A Edgerton stroboscope embodies a 250-watt full-wave rectifier and power supply operated from 110 volt, 60 cycle, a.c., and a mercury arc flashing lamp providing a flash of 5-10 microseconds. The instrument is in a case 8½x15½x24 in., weighs 56 lb. Type 549-A synchronous motor-driven contactor, providing an adjustable flashing speed of 5 to 30 per sec. is available as an accessory, and can be carried in the case.

The stroboscope can be flashed from any source of alternating current, or by externally operated contacts, such as provided by the motor-driven contactor. Maximum flashing speed of the stroboscope is in excess of 150 per sec., providing fundamental synchronism at speeds up to 10,000 r.p.m. General Radio Co., Cambridge, Mass.

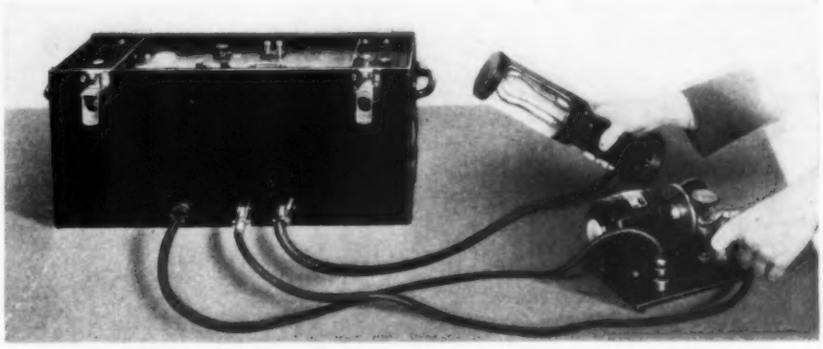
Link-Belt "RC" Flexible Coupling

Consists of two cut-tooth sprocket wheels or coupling halves connected with a piece of roller chain. A pin-and-cotter link is provided to remove the chain. Couplings can be furnished inclosed with stationary or revolving lubricated, oil-retaining casing for protection against dust and dirt. Link-Belt Co., 910 S. Michigan Ave., Chicago, Ill.



New Emerson Motors

Available in single-phase repulsion start induction, polyphase squirrel cage, and compound direct current types operating at 1,725 r.p.m. Motor frames



are ventilated by a fan on the armature shaft. Complete line of motors from 1/250 hp. to 3 hp. are now available. Motors one horsepower or larger are built to NEMA standards with identical mounting dimensions for all types. Emerson Electric Manufacturing Co., St. Louis, Mo.

Ward Leonard Vacuum Contact Relays

For applications requiring non-arcing, quick-acting, positive contact for electrical switching. Device is mounted in metal base. Depth without inclosing

Vacuum Contact Relay for hazardous locations

cover is 1½x4 in. Obtainable in single and double pole. Opens or closes circuit carrying up to 6 amp. continuous or 8 amp. intermittent a.c. or d.c. (non-inductive) at 110 or 220 volts. Ward Leonard Electric Co., Mt. Vernon, N. Y.

NEW BOOKS and PUBLICATIONS

"Vibration Prevention in Engineering"

Arthur L. Kimball, Research Laboratories, General Electric Co. 140 pages, 6x9 in. Clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $2.50.

Although the numerous formulas and equations might give it the appearance of a college textbook, the author has succeeded admirably in fulfilling his intention, as expressed in the preface, of making it a reference book for practicing engineers.

The distinguishing feature of this book is that it tells exactly how to use the formulas that are established. In each instance the equations are derived in a logical manner and the author goes to considerable pains to make sure that nothing will be left to the imagination. At the same time the complex equations whose derivations are not essential to an understanding of the subject matter of the book, are merely presented.

As an illustration of the value of the book to engineers as a reference, in several places the author gives the specific rules that are to be followed in using the equations. This rather unusual procedure will be appreciated by all who might have occasion to use this book.

"Designing for Arc Welding"

Edited by A. F. Davis, vice-president, The Lincoln Electric Co. 416 pages, 5½x8¼ in. Clothboard covers. Illustrated. Published by The Lincoln Electric Co., Cleveland, Ohio. Price $2.50.

Giving in detail the designs of 23 products and structures made chiefly by the electric arc-welding process, this book will be found informative to engineers who are interested in such design work. Each of the papers is one of the 41 prize winners of the Second Lincoln Arc-Welding Prize Competition.

Two of the papers deserve special mention, the ones that were accorded first and second prize in the competition. The first is "The Design and Construction of an Arc-Welded Naval Auxiliary Vessel" by Homer N. Wallin and Henry A. Schade, respectively lieutenant-commander and lieutenant in the U. S. Navy. The second is "Manufacture of Ordnance at Watertown Arsenal Revolutionized Through Arc-Welding" by Major G. M. Barnes, chief of design and engineering, Ordnance Dept., Watertown (Mass.) Arsenal. Both of these articles are replete with detailed design and test data.

Although the above two papers deserve particular mention, it is true of all of the articles that they are thorough in their presentations. In addition to stress calculations and details of constructions, the articles also cover cost estimating, specifications, production methods and testing.

A noteworthy feature of the editing of this book is its division into five design classifications, namely, machinery, ships, buildings and bridges, large containers and pipes and fittings. This division of the contents makes it easy to find the articles dealing with any particular field of design.

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Research Bulletins

University of Illinois Engineering Experiment Station. "An Experimental Investigation of the Friction of Screw Threads." This 60-page bulletin gives a complete description of the tests and results obtained in the investigation of the friction of square threads, Acme and V-threaded screws fitting into bronze, cast-iron and babbitt nuts. The effect of different lubricants, axial loads, speed, temperature, difference in materials, pitch and lead are also analyzed and the results presented. In a six-page appendix is given the result of investigations on the friction of collar thrust bearings. Copies of this bulletin can be obtained by addressing The Engineering Experiment Station, University of Illinois, Urbana, Ill. Price 35 cents.

Mellon Institute of Industrial Research, Pittsburgh, Pa. "A Select, Annotated Bibliography on the Hygienic Aspects of Aluminum and Aluminum Utensile." Since 1926, the Mellon Institute of Industrial Research has been investigating the metals used in the construction of cooking utensils, industrial food-preparation equipment, and of food and beverage containers. The purpose of these researches is to discover the effects of aluminum on foods and food constituents. One phase of this investigation was a critical study of the literature. The findings of that study form the content of this 68-page bulletin. The abstracts cover 150 articles that have appeared in various publications, including foreign ones.

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Arc Lamp Globes—The C. F. Pease Co., 813 N. Franklin St., Chicago, Ill. Folder, "A New Pease Fire-Tested Arc Lamp Globe."

Electric Heating Units—General Electric Co., Schenectady, N. Y. Catalog GEA-1520A (supersedes GEA-1520). "Electric Heating Units and Devices."

Gearmotors — Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Eight-page bulletin, "Westinghouse Gearmotors."

Humidity Indicators & Controls—Julien P. Friez & Sons, Inc., Baltimore St. & Central Ave., Baltimore, Md. Bulletin B, "Friez Complete Control Assemblies," describing the complete control assemblies for air-conditioning apparatus. Bulletin D describes the new Friez relative humidity indicator.

Hypoid Gears — Gleason Works, Rochester, N. Y. Twenty-four-page booklet, "Engineering Data on Large Hypoid Gears."

Linings — Stebbins Engineering & Mfg. Co., Watertown, N. Y. Bulletin No. 1, "Acid, Alkali and Corrosion-Resisting Linings."

Mercury Relay—Struthers Dunn, Inc., 139 N. Juniper St., Philadelphia, Pa. Bulletin P32, "Dunco Mercury Swing-Type Relay."

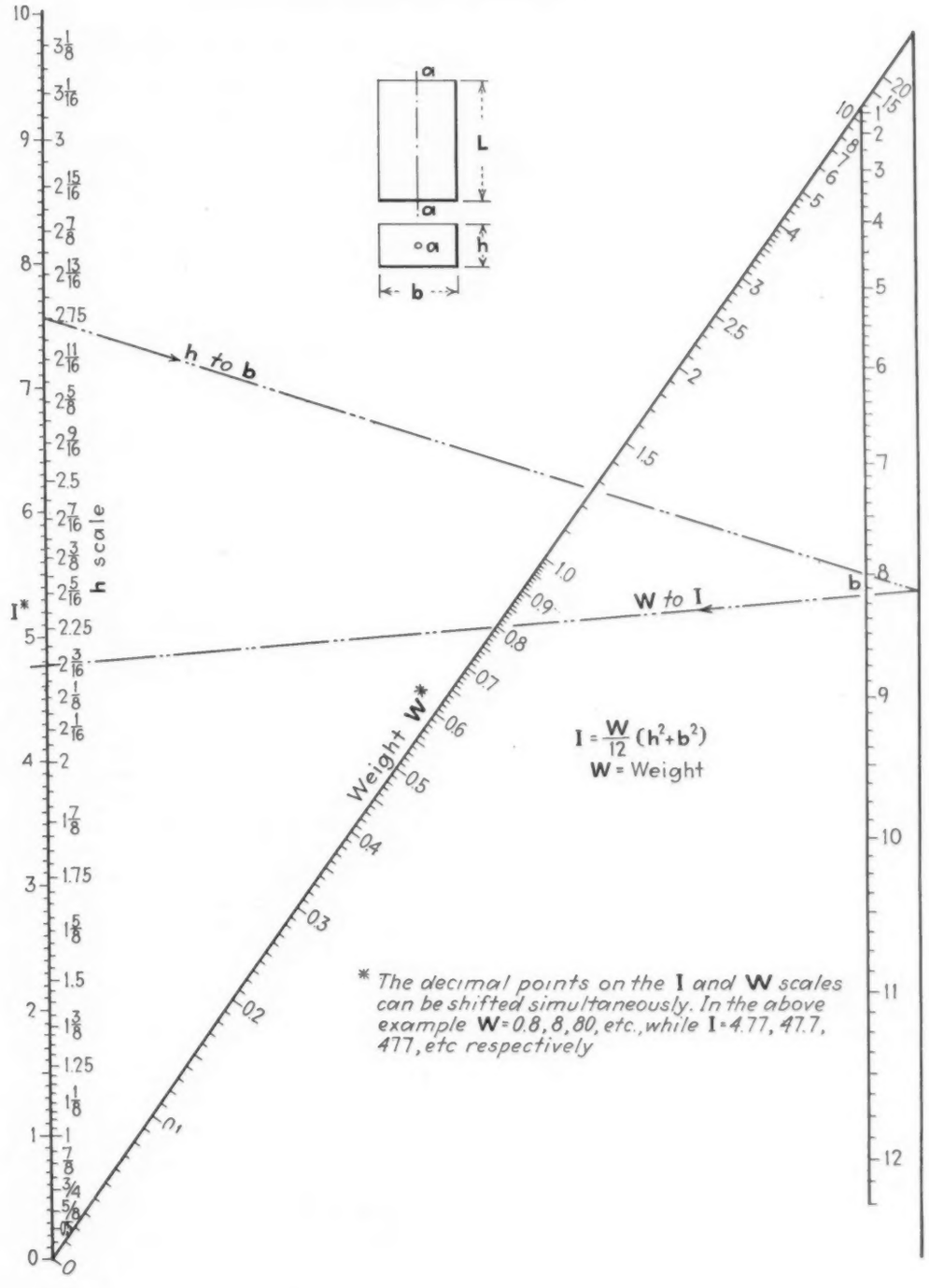
Motors—General Electric Co., Schenectady, N. Y. Bulletin GEA-1618, "Building Motors and Control Into Machine Tools."

Photoelectric Counters — Production Instrument Co., 1315 S. Wabash Ave., Chicago, Ill. Four-page leaflet, "The Electric Eye."

Rubber—Diamond Rubber Co., Inc., Akron, Ohio. Twenty-four-page catalog, "Mechanical Rubber Goods."

Temperature Regulator—Atlas Valve Co., 282-286 South St., Newark, N. J. Bulletin on self-contained vapor-type temperature regulators for liquids.

Moment of Inertia of a Prism About the Axis *a-a*



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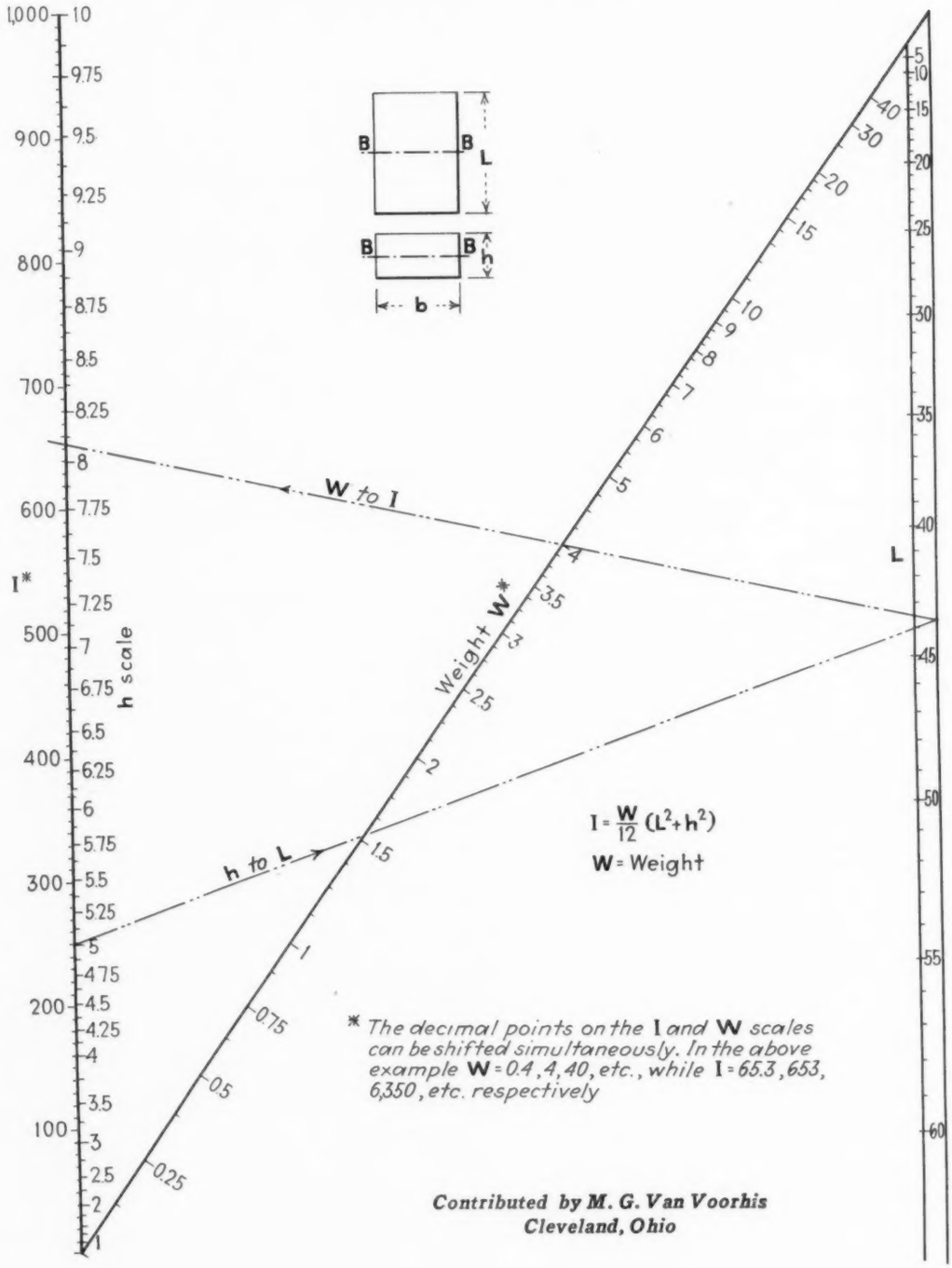
Moment of Inertia of a Prism About the Axis *B-B*



* *The decimal points on the* I *and* W *scales can be shifted simultaneously. In the above example* W = 0.4, 4, 40, *etc., while* I = 65.3, 653, 6,350, *etc. respectively*

Contributed by M. G. Van Voorhis
Cleveland, Ohio

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